UNIVERSITÉ DE MONTRÉAL

CENTRE DE RECHERCHE SUR LES TRANSPORTS

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SUMMARY REPORT

Project EMME

EQUILIBRE MULTIMODAL / MULTIMODAL EQUILIBRIUM

JUNE 1978

Université de Montréal
Publication # 101 - Centre de recherche sur les transports

SUMMARY REPORT

Project EMME

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1. INTRODUCTION

Background

The aim of project EMME was to demonstrate the operational efficiency and validity of a new generation of urban transportation planning techniques which would implement recent advances in the methodology used to estimate demand and simulate traffic flows in large size urban road and transit networks.

Prior to the start of the project, the City of Winnipeg had been approached and it had shown keen interest in cooperating in its realization: it agreed to participate as the urban area selected to demonstrate the proposed new urban transportation planning techniques. The City of Winnipeg already possessed an excellent data bank for transportation planning purposes and it was contemplating a new origin/destination travel survey for the summer of 1976. In addition, the CRT and the City of Winnipeg had successfully collaborated in the past.

The computer-based transportation planning techniques imbedded in EMME can be characterized as integrated two-mode traffic equilibrium methods. Roughly speaking, these methods combine a demand model (which may be a direct demand model or an O-D table coupled with a modal split function) with an equilibrium type car trip assignment and a transit assignment method.[1]

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[1] Florian, Chapleau, Nguyen, Achim, James and Lefebvre, "EMME: A Planning Method for Multi-Modal Urban Transportation Systems", publication # 62, Centre de recherche sur les transports, 1977.

The equilibrium type route choice model for travel by private cars in congested urban areas was validated by a study carried out in the City of Winnipeg. The transit riders' route choice model, which essentially a shortest route choice coupled with diversion among sections served by common bus lines, was tested and implemented at the Montreal Urban Community Transit Commission.

So far, such methods have been usually implemented with fixed origin-destination matrices. The methods imbedded in EMME allow the demand to vary by mode in accordance with the demand model and thus handle in an integrated manner the changes in the origin-destination demand induced by contemplated changes in the road and transit networks. In addition, another aim of the project was to measure and quantify the interaction that occurs between private vehicles and transit vehicles on the road network. This aspect may be particularly important in evaluating the impact of transit innovations such as reserved bus lanes or bus priority rules.

Brief Overview of Project History

The contractual agreement for the project was approved in principle in May 1976 (although the actual contract was signed in June 1977) and the work on the project started on June 1, 1976.

One of the initial task was to establish the network coding standards, data file structures and work files structure. The work on this task resulted in a sizable document that describes in detail all the computer system design as well as all the contemplated data handling and computa-

tional procedures. Throughout the development of the project this document was periodically updated to reflect minor changes in the design of the system, that were dictated from time to time.

Next, Robert Chapleau and Claude Achim collaborated in the development of the interface of the two networks considered, the road network and the transit network. The concept that was adopted employs, as much as possible, the nodes of the road network for the coding of the transit network. The details of the coding procedure are described in detail in [2]. Suitable coding forms were prepared for the specification of the road and transit networks and were provided to the staff of the City of Winnipeg. The coding instructions as well as the concepts employed were discussed with the staff of the City of Winnipeg and the details of the definition of the transit network were prepared by them with our collaboration.

Simultaneous with these tasks, Linda James, Claude Achim and Jacques Lefebvre proceeded to develop the computer system of EMME: that is they developed the codes to interface the road and transit network, coded the assignment routines for the road and transit networks and developed the data bank routines. In particular, in order to check the validity of the data being entered, all the input to EMME's data bank is subjected to a multitude of tests (or edits). These tasks, which may collectively described as the *development and adaptation of computer programs and definition of data files*, were completed by approximately the end of 1977. Although the integrated system was operational

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[2] C. Achim and R. Chapleau, "EMME - Coding the Transit Network", publication #49, Centre de recherche sur les transports, 1976.

sometime in September 1977, revisions and small changes were completed by the beginning of February 1978. Precious time was lost due to the strike at the University's Computer Center which lasted from the beginning of October 1977 until December 29, 1977. (The details of the EMME computer system are given in the system description and are not discussed further in this report.)

In July 1977, Dr. Caroline Fisk joined the project team and was assigned to develop a set of computer graphic programs that are compatible with the EMME data bank. These capabilities include the link (line) and node diagrams of the road (transit) network and the drawing of traffic (transit) flows on the appropriate network. The addition of the graphical outputs enhances the ease of use of EMME, since it permits the user a quick overall appreciation of the impacts of a given scenario.

In addition to the graphical outputs, Claude Achim and Linda James with assistance from Robert Chapleau and Sang Nguyen, have prepared a set of analysis programs that enable a quick analysis of the detailed results provided by the various assignments permitted by EMME. These programs served in the initial phase of the project to validate the road and transit networks, and later, to evaluate the impacts of the scenarios considered and were available by the middle of 1977. These programs are compatible with EMME, however are not part of the basic system, since, among other reasons, their utilization depends on the type of plotter available at any given computer installation.

In parallel with the development of the computer system of EMME, work was done on the collection of relevant data for the *calibration of the bus/auto travel time relationships*, the *recalibration of the volume/delay curves* and the *validation of the road and transit networks*.

The City of Winnipeg carried out in the summer of 1976 a speed/delay study, which consisted of measuring link volumes and link auto travel times for approximately 80%-90% of the streets in the regional street system. In addition, bus travel times were measured for 446 transit line sections. This data served to re-calibrate the volume/delay curves that were used for the 1971 road network, and to calibrate the bus/auto travel time relationships.

Claude Achim, with technical assistance from Robert Cléroux, Robert Chapleau and with the co-operation of Jarvis Kohut and Ed Guertin, proceeded to analyse the bus/auto travel time data. After numerous functional forms were tried and many regressions were run, it became apparent that four travel time relationships were indicated: the express bus lines are assigned speeds equal to the auto speeds and the feeder lines are assigned constant average speeds; for buses that use road links where the average speed is larger than 10 mph the function used is TMB = 2.15 + TMA (Time per Mile Bus/Auto) and for links where the average speed is less than 10 mph the function used is $TMB = TMA + 2.1\sqrt{TMA}$. The details of the analysis are described in section 2 of this report.

In parallel with the above analysis, Linda James with assistance from Sang Nguyen and with the co-operation of Ed Guertin, re-calibrated the volume/delay curves and re-classified certain links. In addition, the

functional form of these curves was changed from the formula used by the TRC, which is

$$s_a(v_a) = d_a \{\delta + \alpha (\frac{v_a}{\ell_a} - \gamma) + (\alpha^2 (\frac{v_a}{\ell_a} - \gamma)^2 + \beta)^{\frac{1}{2}}\}$$

to the simpler BPR formula

$$s_a(v_a) = d_a \{t_o + \alpha (\frac{v_a}{c_a})^\beta\}$$

where d_a is the link length, v_a is the link volume, ℓ_a is the number of lanes of the link, c_a is the practical capacity of the link and the other parameters are calibrated from the observed data. The details of the analysis are described in section 3 of this report.

The bus/auto travel time relationships and the volume/delay curves were integrated with the coded road and transit networks and were used for the determination of the auto and transit origin-destination matrices.

During the summer of 1976, the City of Winnipeg carried out an origin-destination of trips taken from home to work. A 17% sample of households was sampled and a separate survey of 23% of student trips was performed at about the same time. The raw data, consisting of the individual responses, were transmitted to us by the City of Winnipeg in the spring of 1977, somewhat later than we had anticipated at the beginning of the project. Since all the analysis is done for the 7:30 - 8:30 AM peak hour one of the first tasks considered was to define the so-called "departure codes", that is, the starting time of trips that will be using the road and transit networks during the peak hour. The departure codes were determined initially by the City of Winnipeg staff and were first specified

by origin, using a subdivision of origins into 36 super zones. The use of this subdivision is indicated in Figure 1.1. By using the departure codes, the corresponding trips are extracted from the survey data and multiplied by the appropriate expansion factors to obtain an estimate of the *total person work trips* taken in the peak hour by each mode. Then, the total auto work trip matrix is scaled by appropriate car occupancy factors in order to obtain the *total auto work trip* matrix.

This matrix was then assigned to the road network and compared with the observed link volumes. Since only the work trips are sampled during the O/D survey, it was necessary to develop a set of adjustment factors (or factors) that multiply the number of trips in the *total auto work trip* matrix in order to reflect auto trips that are taken for other purposes than work and a certain amount of truck traffic. These factors are specified by origin for a subdivision of origins into 10 super zones which are indicated in Figure 1.2. The determination of the most appropriate factor is a trial and error procedure, where a factor is tried, the resulting assignments are compared to observed link flows and then a new factor is determined which is hopefully more appropriate. Five factors were tried until satisfactory results were obtained. In addition, it turned out that trips to the University of Manitoba (zone 59) required special departure codes, which were specified for the subdivision of origins into 10 super zones, since this zone is relatively more distant from most origins. In the EMME computer system, the factors are converted into a *vehicle adjustment trip matrix* which is added to the *total auto work trip* matrix for the purpose of the assignment. (See Figure 1.2 for the factors table.)

1976 O-D STUDY

TIME ADJUSTMENTS TO A.M. PEAK HOUR

TRIP ORIGIN SUPERZONE	TRIP DIRECTION	MODE OF TRAVEL			
		AUTO DRIVER	AUTO PASSENGER	BUS PASSENGER	WALK/CYCLE
1-11	FROM HOME TO WORK	(7,4)(8,1-3)	(7,4)(8,1-3)	(7,4)(8,1-3)	(8,1-4)
	FROM WORK TO HOME	(8,1-4)	(8,1-4)	(8,1-4)	(8,1-4)
12-21	FROM HOME TO WORK	(7,4)(8,1-3)	(7,4)(8,1-3)	(7,4)(8,1-3)	(8,1-4)
	FROM WORK TO HOME	(8,1-4)	(8,1-4)	(8,1-4)	(8,1-4)
22-36	FROM HOME TO WORK	(7,3-4)(8,1-2)*	(7,3-4)(8,1-2)*	(7,3-4)(8,1-2)	(8,1-4)
	FROM WORK TO HOME	(8,1-4)	(8,1-4)	(8,1-4)	(8,1-4)

* EXCEPT FOR TRIPS ORIGINATING IN SUPERZONES 22-36 & DESTINED TO SUPERZONES 22-36, THEN USE (7,4)(8,1-3)

Figure 1.1

NOTE (8,1-4) = 7:30-8:30 AM, (7,4,8,1-3) = 7:15-8:15 AM & (7,3-4)(8,1-2) = 7:00-8:00 JULY 6, 1977

THE CITY OF WINNIPEG

WORK TRIP TO TOTAL TRIP
EXPANSION FACTORS
1976 AM PEAK VEHICLE TRIPS

Factor 5

O \ D	0	1	2	3	4	5	6	7	8
0	2.106	2.428	1.981	1.846	2.111	2.000	1.931	2.625	[illegible]
1	1.167	1.584	1.199	1.199	1.135	1.170	1.167	1.149	[illegible]
2	1.150	1.595	1.210	1.210	1.135	1.255	1.198	1.198	[illegible]
3	1.159	1.474	1.166	1.166	1.135	1.170	1.159	1.150	[illegible]
4	1.365	1.358	1.070	1.067	1.122	1.210	1.365	1.319	[illegible]
5	1.226	1.153	1.029	1.029	1.122	1.155	1.226	[illegible]	[illegible]
6	1.364	1.333	1.333	1.333	1.434	1.425	1.364	[illegible]	[illegible]
7	1.823	2.164	1.649	1.654	1.434	1.840	[illegible]	[illegible]	[illegible]
8	1.552	1.990	1.449	1.448	1.435	1.543	1.465	1.552	[illegible]
9	1.319	—	—	—	1.234	—	—	1.211	—

AUG 30,

Figure 1.2

1/9/77

Once fixed origin-destination matrices were determined, work was started on the calibration of the modal split function. Serge Galarneau with the assistance of Claude Achim, Robert Cléroux, Michael Florian and Marc Gaudry carried out this part of the project, with advice coming from most of the team members and the staff of the City of Winnipeg. Due to the large size of the sample it was decided to calibrate zonal aggregate logit type modal split functions, which are of the general form

$$p_r(\text{bus}) = \frac{1}{1 + \exp\left(k_o + \sum_i c_i x_i\right)}$$

where k_o and c_i are calibrated from the data and x_i are the independent explanatory variables. For the purpose of the calibration we obtained the auto travel times from the road network assignment and the transit impedance (or generalized cost) from the calibration of the transit network assignment; in addition we had zonal average values for several socio-economic variables which are described in detail in section 6 of this report. A very large number of trials were carried out that used various functional forms and various combinations of explanatory variables. The best results were obtained by subdividing the origins into 4 subgroups, which were determined by exploratory data analysis, and calibrating a modal split function for each subgroup. In addition, the functions were calibrated by using only origin-destination pairs that had more than 60 total trips in the expanded origin-destination matrices. It is worthwhile to mention that this task consumed far more time than expected, however the results that were obtained are very satisfactory.

Next and last in the tasks of the project, we proceeded to analyse the scenarios provided to us by the City of Winnipeg, the Fort Garry - St. Vital river crossing and the South West Transit Corridor.

During this time, Claude Achim and Robert Chapleau, with assistance from Jarvis Kohut and other members of the staff of the City of Winnipeg, worked on the calibration and validation of the transit network. This task required about 6 stages of development, which are described in detail in Section 5 of this report. A series of computer program executions was carried out in order to validate the network and then another sequence of transit assignments was further performed in order to validate the transit network. The total elapsed time for the calibration and validation of the transit network was about one year.

Description of Scenarios

We were provided by the City of Winnipeg with a road improvement scenario and a transit improvement scenario.

The road improvement scenario consists of the addition of a bridge and access roads across the Red River joining the Fort Garry and St. Vital community areas. The bridge has four lanes between the Pembina Highway and St. Anne's Rd. and two lanes from there until it meets the Lagimaudiere Blvd. The project involves as well an extension of Dakota Street to the site of a new shopping centre. This scenario involved the addition of 19 nodes and 96 links to the road network. The corresponding subnetwork is given in Figure 1.3.

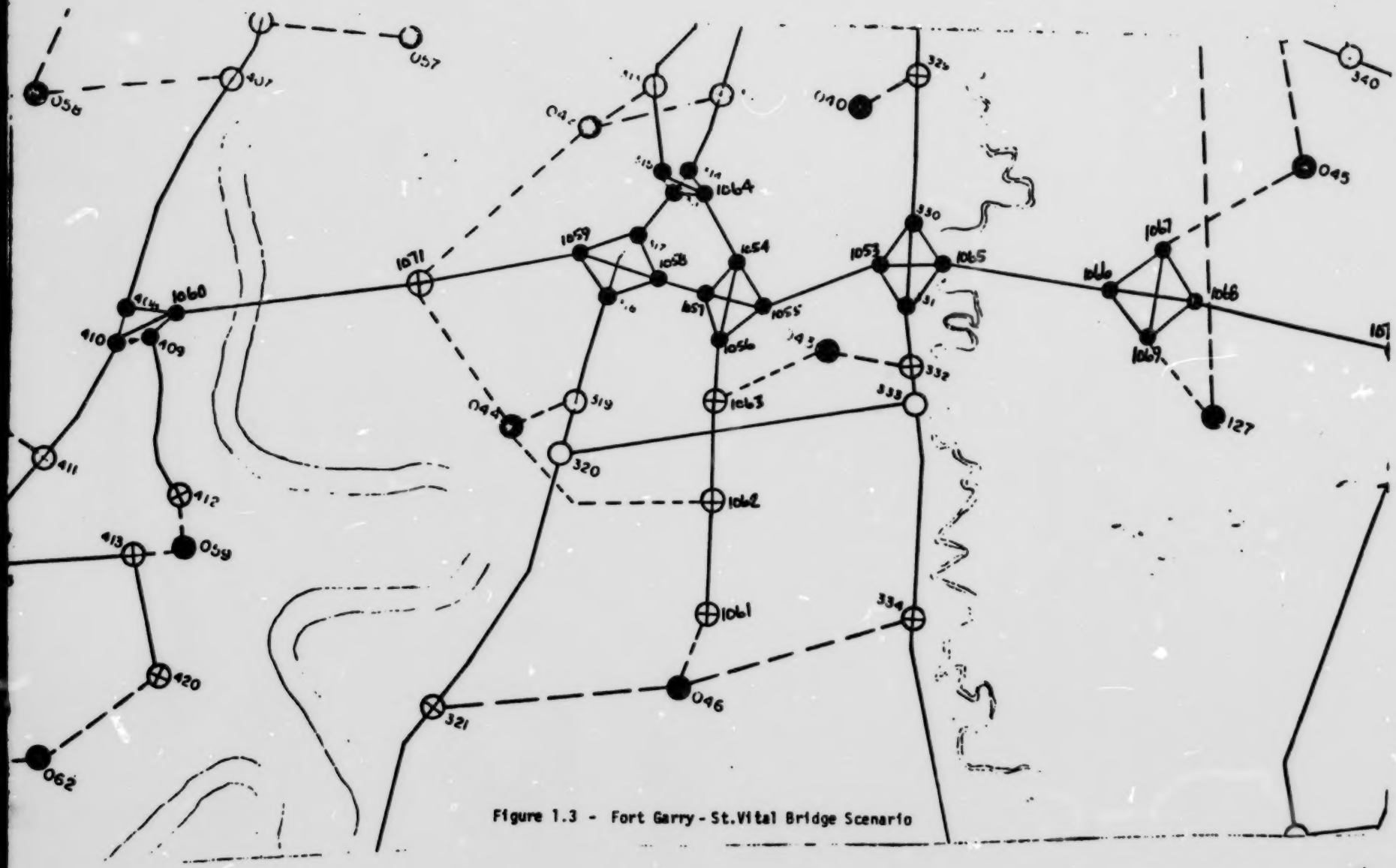

Figure 1.3 - Fort Garry - St.Vital Bridge Scenario

The transit improvement scenario is the Southwest Transit Corridor. In May 1975, the City of Winnipeg, in co-operation with the Province of Manitoba and the Federal Government, initiated the Southwest Transit Corridor Study. The objective of the study was to examine the feasibility of implementing a new rapid transit system on its own right of way between the downtown area and the University of Manitoba. The study carried out by De Leuw-Dillon in association with the Lombard North Group. recommended a busway route along a two lane roadway[3] extending for 6.75 miles between Bison Drive in Fort Garry and Pioneer Avenue in the downtown area. The operation of buses in that region of the town would be reorganized to take advantage of the busway: the buses would circulate through the local neighbourhoods, the University and the downtown area using the local street system; then they would run via the busway to provide fast service between areas of the corridor and the downtown. More specifically 3 lines are affected: lines 13 and 41 will be using the busway and every third bus of line 40 will be using the busway as well. On the transit network this scenario resulted in the removal of two lines (13 and 41), modifying the frequency of one line (40) and the addition of three new lines (13, 41 and 40 on busway).

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3 DeLeuw-Dillon with the Lombard North Group Ltd., "Winnipeg Southwest Transit Corridor Study - Report on Phase II: Recommended System" September 1977.

2. THE BUS/AUTO TRAVEL TIME FUNCTION

The purpose of this task of the project was to develop a model that relates the travel time of a transit vehicle on a road link to the corresponding travel time for private cars. The model will be used to take into account the change of transit travel times, as a result of a change in the congestion level of a road link.

The data that were needed to develop this model are road link lengths, observed car travel times on those links and the corresponding bus travel times. The road link lengths and car times were available from the road network data. The City of Winnipeg provided us with observed bus travel times for line sections (a line section is considered to be defined as a sequence of the corresponding road links).

We first created a data file, using the data provided to us by the City of Winnipeg, that contains for each line section, the following information:

- starting node
- ending node
- direction (inbound or outbound)
- line number
- observed bus time
- observed car time (for the complete sequence of links)
- minutes per mile for the bus on the section
- minutes per mile for cars on the section
- number of road links in the section

The file contains observations for 470 line sections. On 25 segments, the observed transit time was smaller than the observed car time. Since

this problem seems to be related to the accuracy of the data, these observations were not considered in the calibration of the model.

We shall now describe the analysis we performed on the above data. But first we shall introduce some notation: Let

TA : auto time on the line section (minutes)

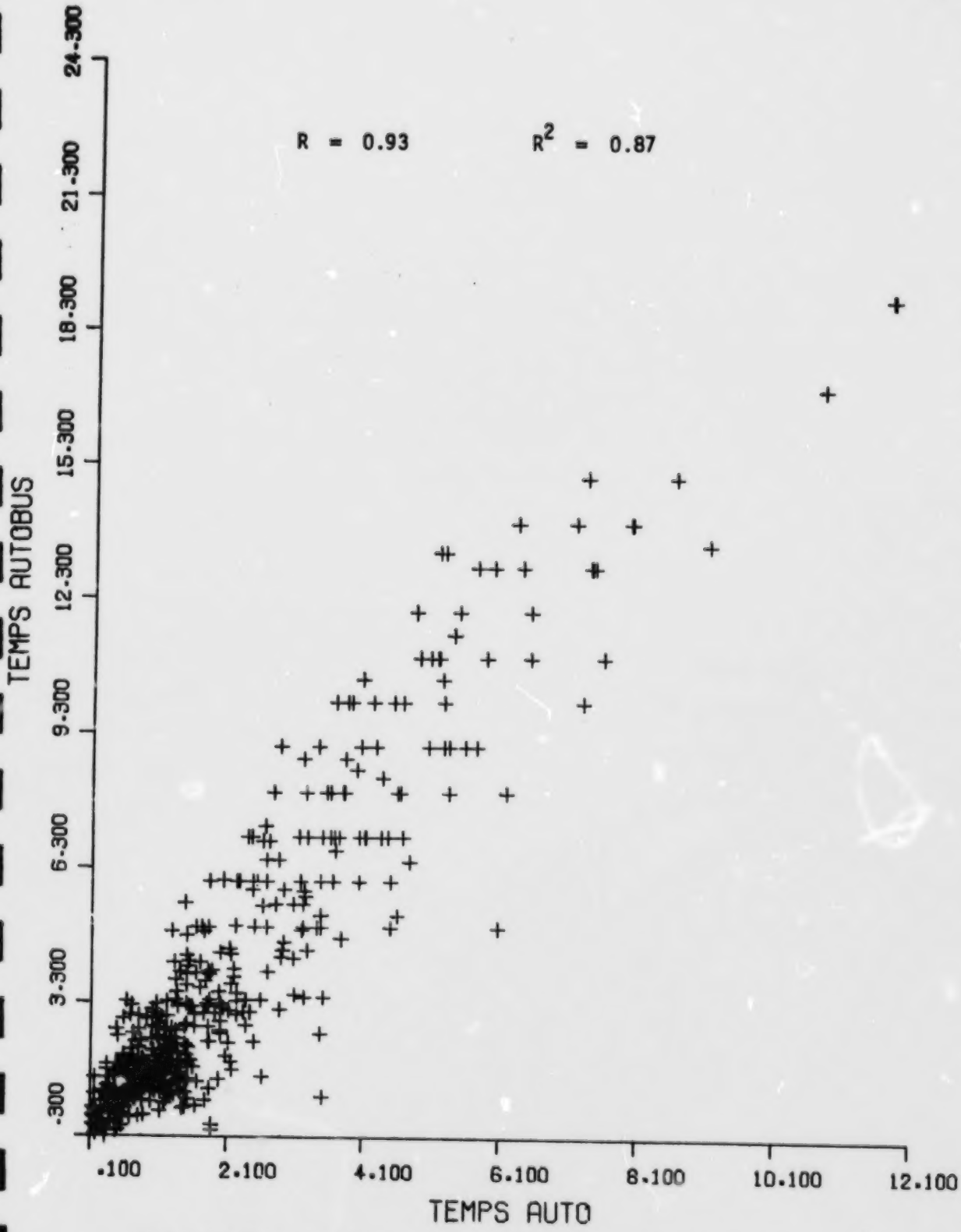
TB : bus time on the line section (minutes)

TMA: auto time per mile on the line section (minutes/mile)

TMB: bus time per mile on the line section (minutes/mile)

First, we plotted TB as a function of TA. Figure 2.1 shows the scatter diagram; a linear function was fitted resulting in an R^2 of 0.87. However, some contemplation of this relationship reveals that its only meaning is that over long sections, both the car and the auto will take a long time, and, of course, on short sections, both times will be small (that is they are both correlated to link length). Furthermore, such a model would not capture any effect of congestion.

For those reasons, we proceeded to a comparison of speeds or, more exactly, the inverse of speed, time by mile, (which is used in the formulation of volume-delay curves). A simple linear model of TMB vs TMA resulted in a poor fit of $R^2 = 0.2$. A linear model of TMB vs TMA and TA, increased the R^2 to 0.49 which, again, was not satisfactory. In both of the above cases, we tried different models for the inbound and outbound direction but the fits, reflected in the R^2 values, were not improved.



TOUTES LES LIGNES ET DIRECTION

Figure 2.1

A plot of (TB/TA) vs TMA showed that a nonlinear model could be more appropriate (fig. 2.2). An exponential model of the form

$$\ln [(TMB/TMA) - 1] = a_0 + a_1 \, TMA$$

was estimated by linear regression. Again, with an $R^2 = .09$, the model was rejected. We then attempted to use a polynomial model of the form

$$(TMB/TMA) - 1 = a_1 \, (TMA)^{-1/2} + a_2 \, (TMA)^{-1} + a_3 \, (TMA)^{-3/2} + a_4 \, (TMA)^{-2}$$

which was estimated with a stepwise linear regression. The only term that entered in the regression was $a_1 \, (TMA)^{-1/2}$ and it gave an R^2 of .62 which, considering the accuracy of the data, was the first satisfactory result obtained. The analytical form of this model, which we shall call M1, is:

$$(TMB/TMA) - 1 = 1.97 \sqrt{1/TMA}$$

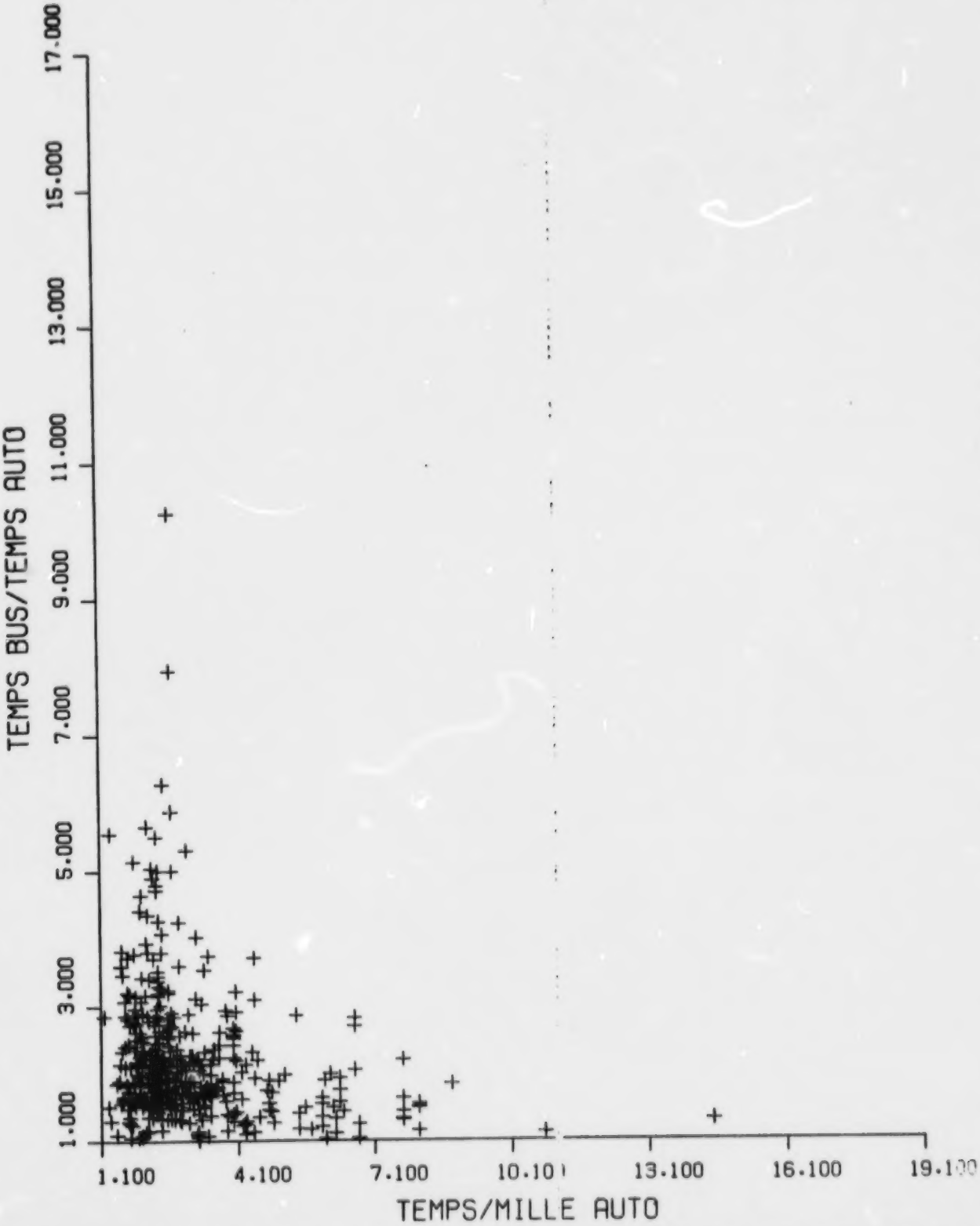
or

$$TMB = TMA + 1.97 \sqrt{TMA} \qquad \text{(M1)}$$

As an alternative, we considered a linear model of the form $TMB = m \cdot t_0 + TMA$, where t_0 is the inverse of the free flow speed of the road link. t_0 values were obtained from the road network data. A linear regression gave an R^2 of .62; the model, denoted M2, is as follows

$$TMB = TMA + 1.43 \, t_0 \qquad \text{(M2)}$$

where $1.43 \, t_0$ is a constant penalty in minutes per mile for transit vehicles, which is related in some way to the link type.



TOUTES LES LIGNES, TOUTES DIRECTIONS

Figure 2.2

(Values of TB/TA < 1 are excluded)

The next step was to make an evaluation of the predictive ability of models M1 and M2. Since we are most interested in predicting good transit impedances (origin to destination path times), we decided to compare for each line and each direction in the data file the sum of the predicted travel times on each section against the corresponding observed times. The results were good for most of the lines (within 10%) except for express services and for some high speed regular lines.

It then became evident that a natural way to improve the models was to stratify the data according to service type. The three types considered were:

- feeder (0 observations in data file)
- regular (426 observations)
- express (44 observations)

Models of the same form as M1 and M2 were estimated for the express service. The R^2 were close to 0.5 and the models were not significant because of the rather small number of observations available. In the case of regular service, the recalibration of models M1 and M2 resulted in the ralations:

$$TMB = TMA + 2.1 \sqrt{TMA}$$

$$TMB = TMA + 1.49 \; t_o$$

The R^2 improved slightly (0.64) but overall, the models did not change significantly. We then subdivided the regular service into two categories by considering the average observed speed of each line. All the lines running below 10 mph were classified as "regular" and the others as "fast regular".

For the "fast regular" lines, the recalibration of the model M1 results in

$$TMB = TMA + 2.15 \quad , \quad R^2 = .84$$

and of the model M2 in

$$TMB = TMA + 0.9\, t_o \quad , \quad R^2 = .84$$

For the regular lines, model M1 becomes

$$TMB = TMA + \frac{9.14}{\sqrt{TMA}} \quad , \quad R^2 = .78$$

and the model M2 becomes

$$TMB = TMA + 2.12\, t_o \quad , \quad R^2 = .73$$

This time the comparison, for each line and direction, of the sum of observed and predicted times on each section showed that TMB = TMA + 2.15 is a good model for fast regular lines. In the case of regular lines, both models had to be rejected. Our next step in the analysis of the regular lines was to go back to the previous form of the model, that is, to estimate a function of the form

$$TMB = TMA + \alpha\sqrt{TMA}$$

which had proved to be satisfactory for regular lines, except for the fast ones. The estimation resulted in an $\alpha = 3.21$ and an $R^2 = .73$. Unfortunately, the comparison of the sum of line section times showed that the previous model ($\alpha = 2.1$, $R^2 = .64$), which had been estimated on all regular lines data (fast regular + regular), gave better results that the new one which had been estimated on by using data for regular lines (< 10 mph) only!

All the above analysis suggested that it may be advantageous to define fast regular lines by using a higher speed value. But, experiments indicated that the results could not be improved in this way.

Considering the above analysis, and the fact that we did not have sufficient data for feeder and express services, we finally selected and implemented the following bus travel time relationships:

On transit-only links, the user-defined travel times are used.

On transit links corresponding to road links four cases are considered:

For a feeder service (line type 3) the user-defined line speed is used on all the links, independently of car speed.

For an express service (line type 1) the bus speed is the same as car speed: TMB = TMA.

For a fast regular service (line type 2) we have: TMB = TMA + 2.15 (regular lines with a commercial speed of 10 mph or more were considered as fast lines).

For a regular service (undefined line type) we have:

$$TMB = TMA + 2.1 * \sqrt{TMA}$$

where TMB = minutes by mile for bus

TMA = minutes by mile for automobile.

We were now ready for the final part of this task, which was the evaluation and fit of the bus/auto travel time model on the complete Winnipeg transit network. The relationships were applied to predict the transit travel time on each of the 1755 transit links of the coded network. On the basis of those predicted times, transit paths between selected O-D pairs were calculated.

The transit times and paths were analyzed by Jarvis Kohut in Winnipeg, who then suggested that we should change the classification (type) of some of the lines. After a few iterations of this procedure, we finalized the classification for all of the lines.

We would now like to conclude with some remarks:

- A fringe benefit of having included a bus time model in EMME is that the user does not have to define a travel time for each of the transit links; thus, the coding of the network is made much easier.
- An important consideration in this analysis is that the bus/auto travel time model should reflect the real attraction of a transit line (in terms of passenger behaviour); in other words, it must yield "good" transit impedances. Therefore, in the transit assignment calibration phase, we had to change the classification of a few lines to reflect the perception of the transit passengers.
- Following the suggestion of Mr. Ma, we have investigated the possibility of introducing the number of bus stops per link as an independent explanatory variable but, on one hand such data were not available, on the other hand the ease of coding the network would have been lost. Also, we did not find much support for this hypothesis among the staff of the City of Winnipeg.

3. RECALIBRATION OF THE VOLUME/DELAY CURVES

Modification of the functional form of the curves

In order to simplify the recalibration of the volume/delay curves by using the 1976 observed link volumes and travel times, we modified first the analytical form of these curves by replacing the TRC formula

$$S_a(v_a) = d_a\{\delta + \alpha\,(\frac{v_a}{\ell_a} - \gamma) + (\alpha^2\,(\frac{v_a}{\ell_a} - \gamma)^2 + \beta)^{1/2}\}$$

the simpler BPR formula

$$S_a(v_a) = d_a\,\{t_o + \alpha\,(\frac{v_a}{c_a})^{\beta}\}$$

as we had mentioned in the introduction, where d_a is the link length, v_a is the link volume, ℓ_a is the number of lanes of the link, c_a is the practical capacity of the link and the other parameters are calibrated from the observed data.

The initial transformation to the BPR form was made by David Branston[1]. He estimated a practical capacity for each of the TRC volume/delay curves and calibrated the constants α, β of the BPR formula by using the times predicted by the TRC formula. The results of this calibration are shown in Figures 3.1 to 3.4. The solid line shows the BPR curve and the points indicate the times predicted by the TRC function. (The set of values α, β and t_o are identified as BPR1.)

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[1] BRANSTON, D., "Link Capacity Functions: A Review", publication #26, Centre de recherche sur les transports, Université de Montréal, June 1975. (Also published in Transportation Research)

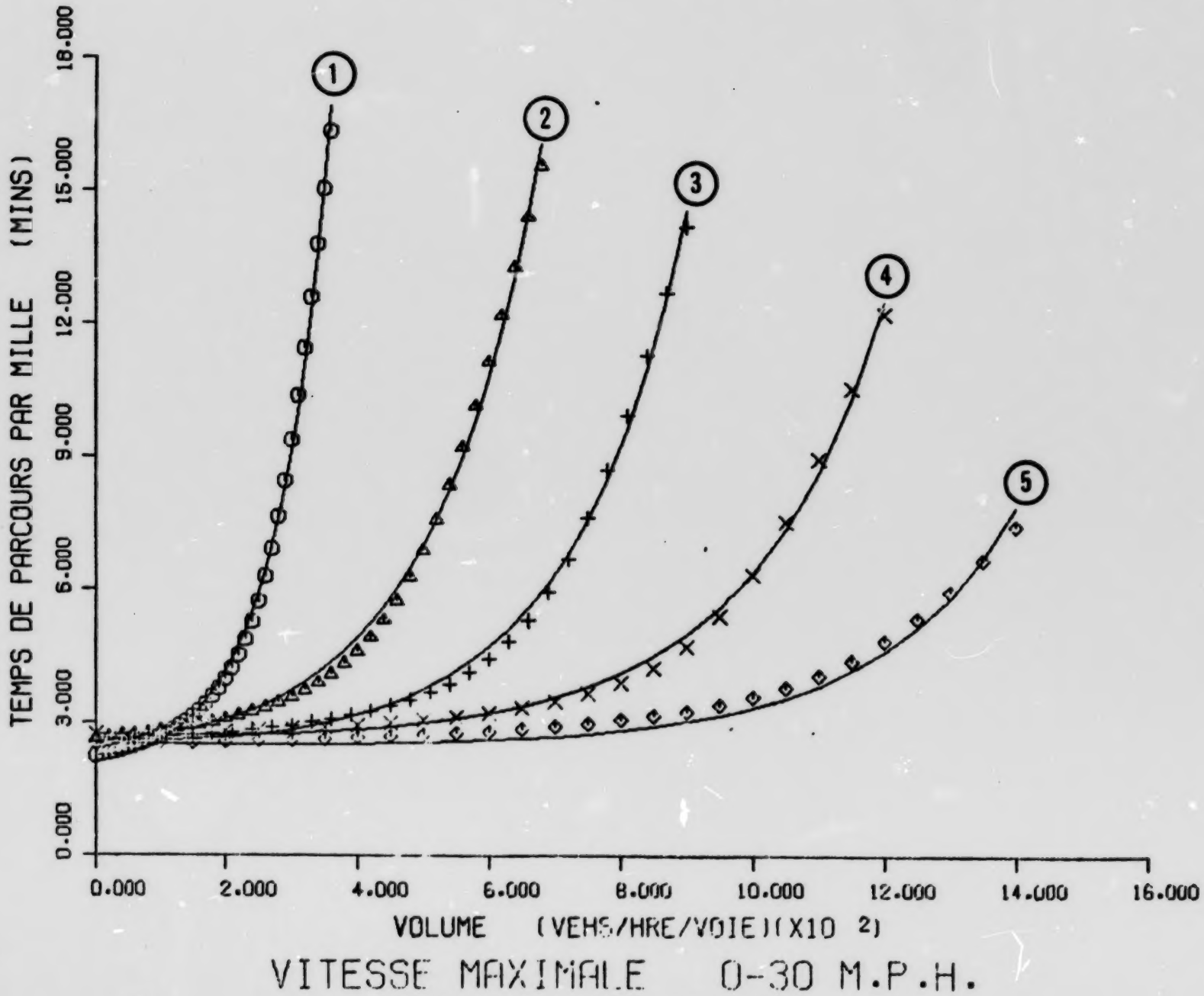


Figure 3.1 - TRC vs. BPR curves

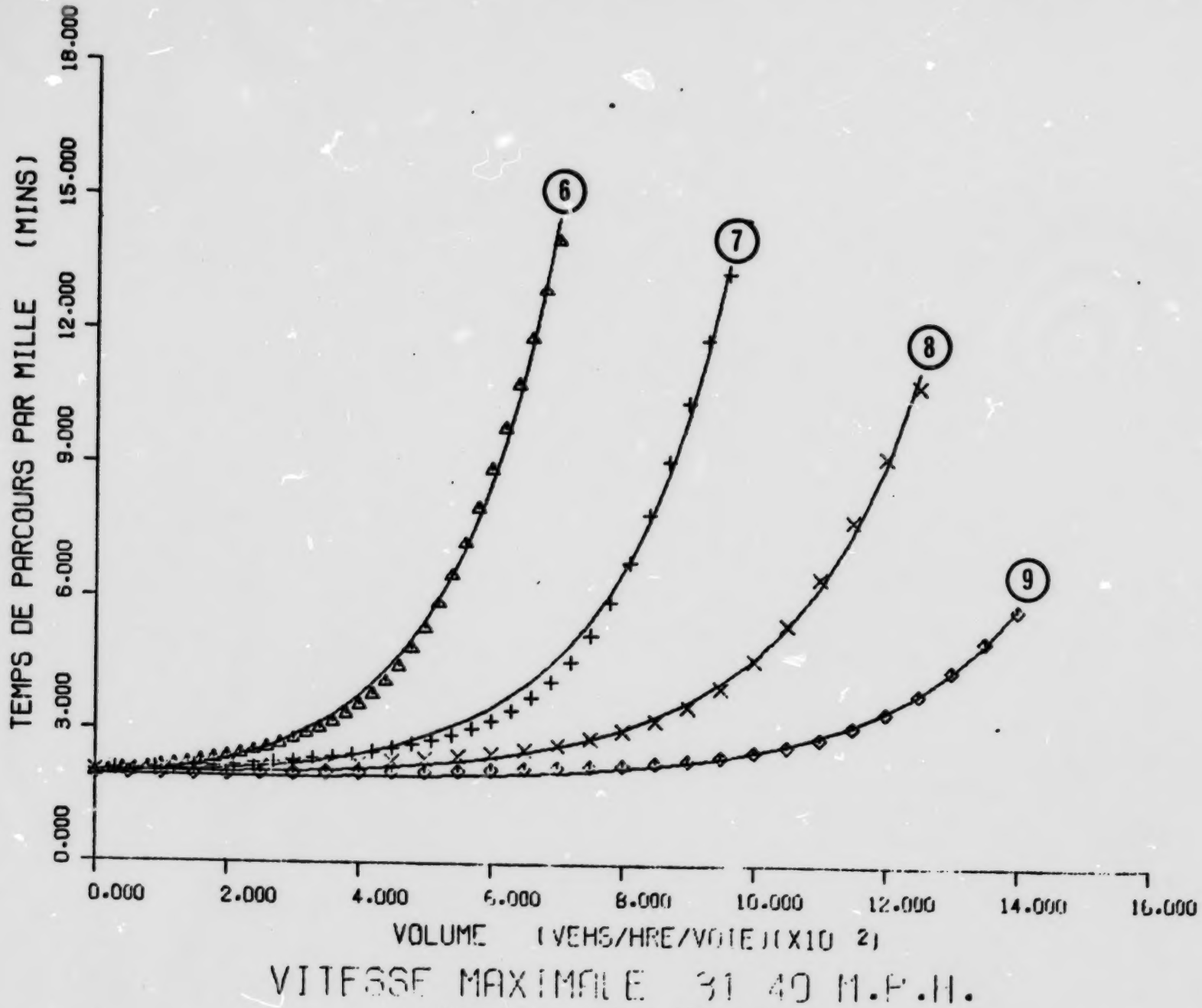


Figure 3.2 - TRC vs. BPR curves

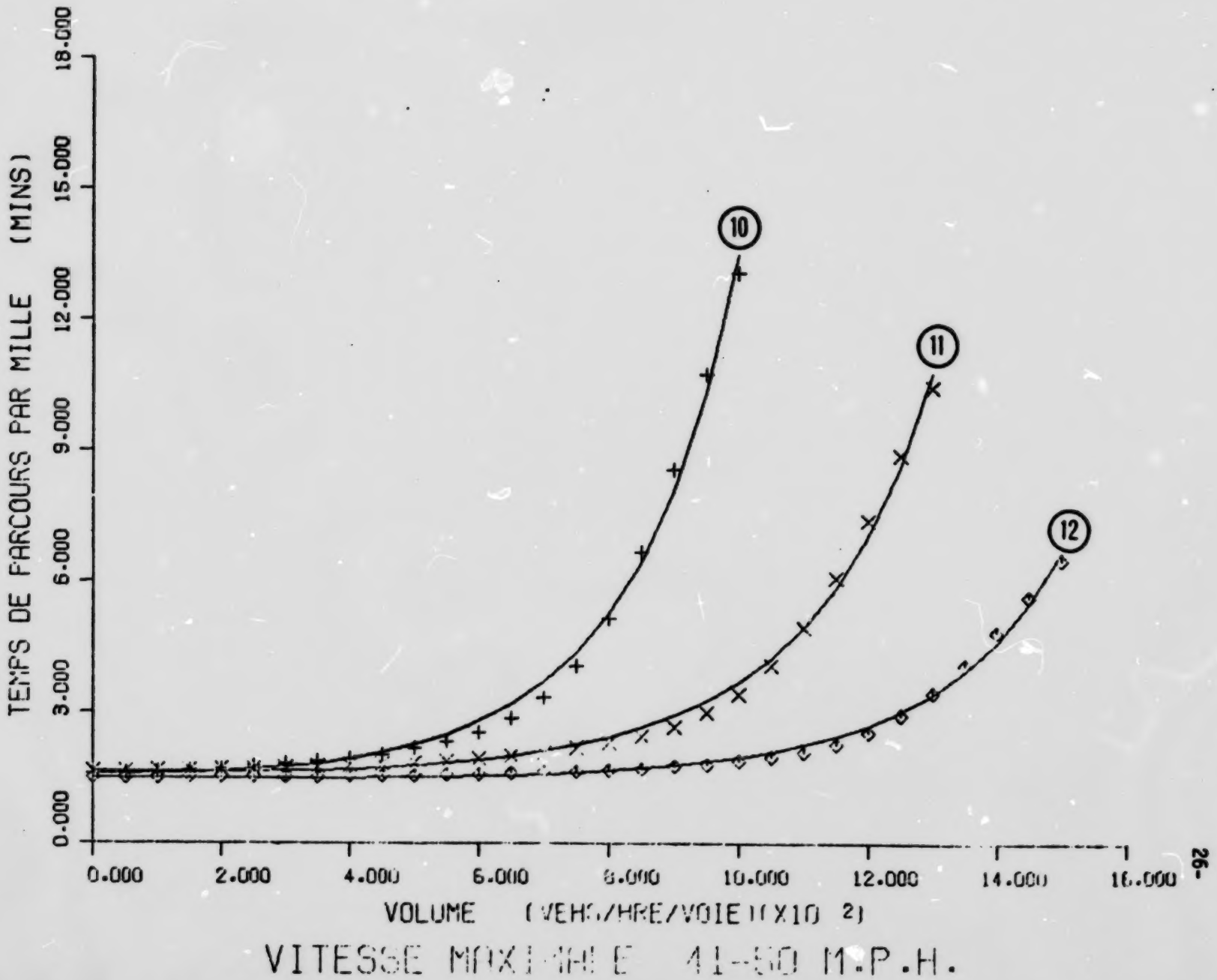


Figure 3.3 - TRC vs. BPR curves

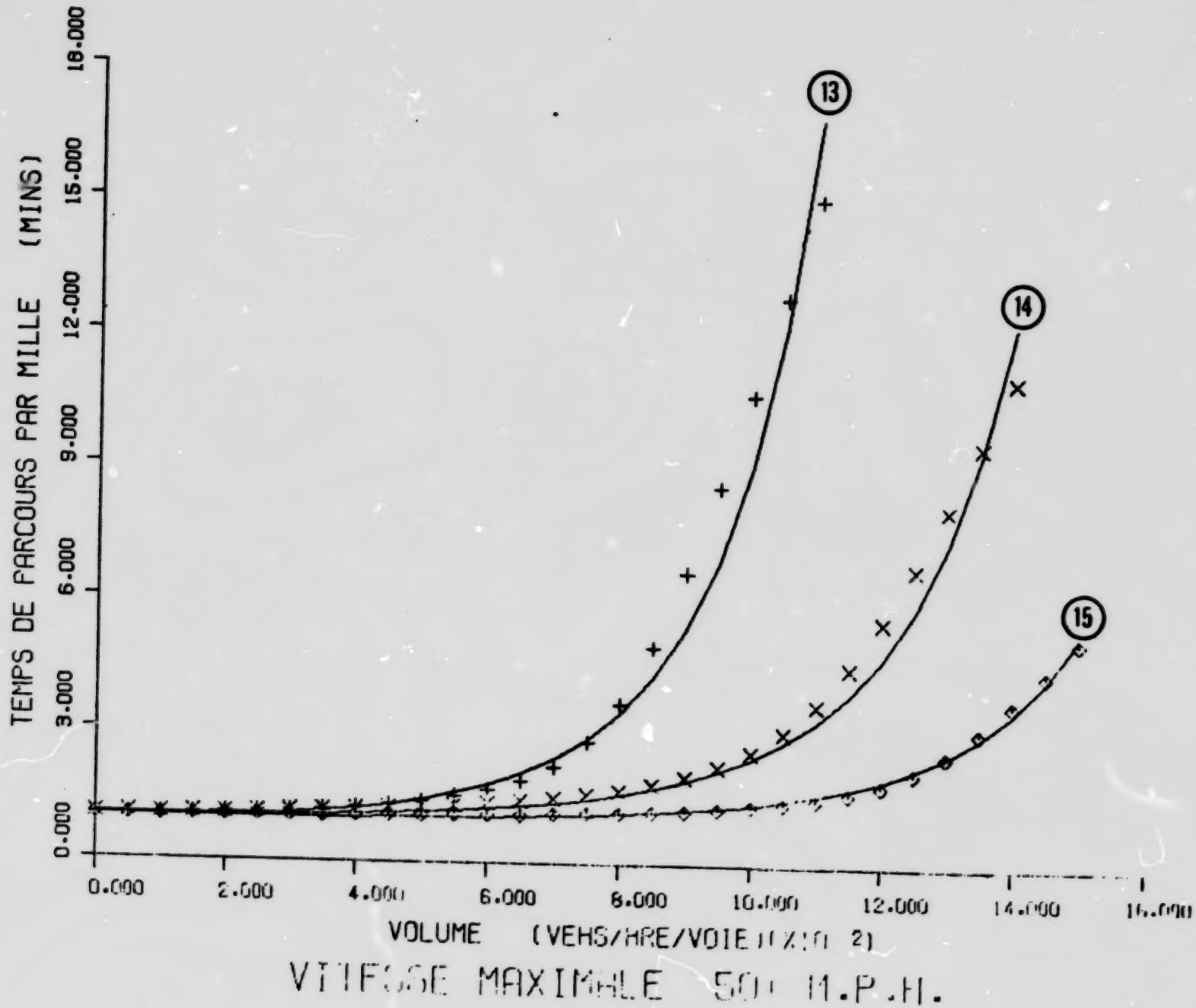


Figure 3.4 - TRC vs. BPR curves

We then proceeded to recalibrate the BPR curves obtained in this way by using the 1976 data by using the following procedure. For each volume/delay curve, the observed data was aggregated by using a subdivision of the link volumes v_a into intervals, and mean values were computed for each interval. The curves and the resulting mean values of the travel times were plotted as shown in Figure 3.5. These plots were analysed in cooperation with Ed Guertin; as a result new free flow speeds were determined and then, the curves were replotted. This procedure was repeated three times, resulting in a set of α, β and t_0 which we identified as BPR4. Figure 3.6 shows the final volume/delay curve and the travel time means (as in Figure 3.5) and the details are shown in Appendix 1.

Reclassification of the volume/delay curves

It was evident from the plots used to determine the free flow speed, that for certain links, that exhibited observed times below and to the right of the curves, would be better predicted by delay curves representing higher capacity links. In order to assist the City of Winnipeg in this reclassification of links to different curves, a report was produced for all links for which an observed flow was available. This report gives the time predicted by the currently assigned curve and also other curves which would predict the travel time better while respecting the speed limit. A page from this report is shown in Figure 3.7. 'NONE' in the 'Suggested curve' column indicates that the capacity assigned curve number (CACO) predicts the travel time better than any other curve. Ed Guertin used this report to reclassify

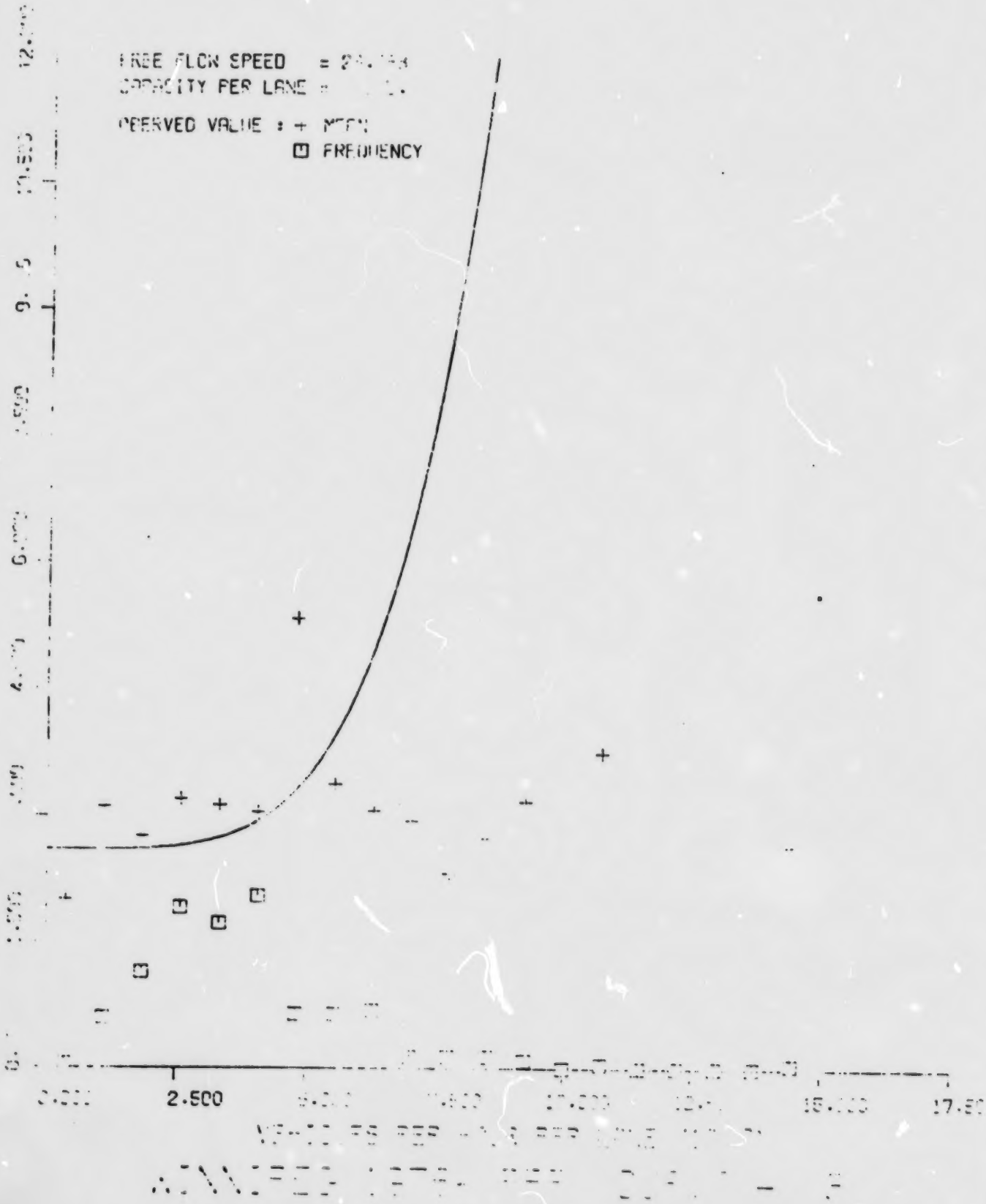


Figure 3.5 - Free Flow Speed as Calibrated by TRC (23.083 mph)

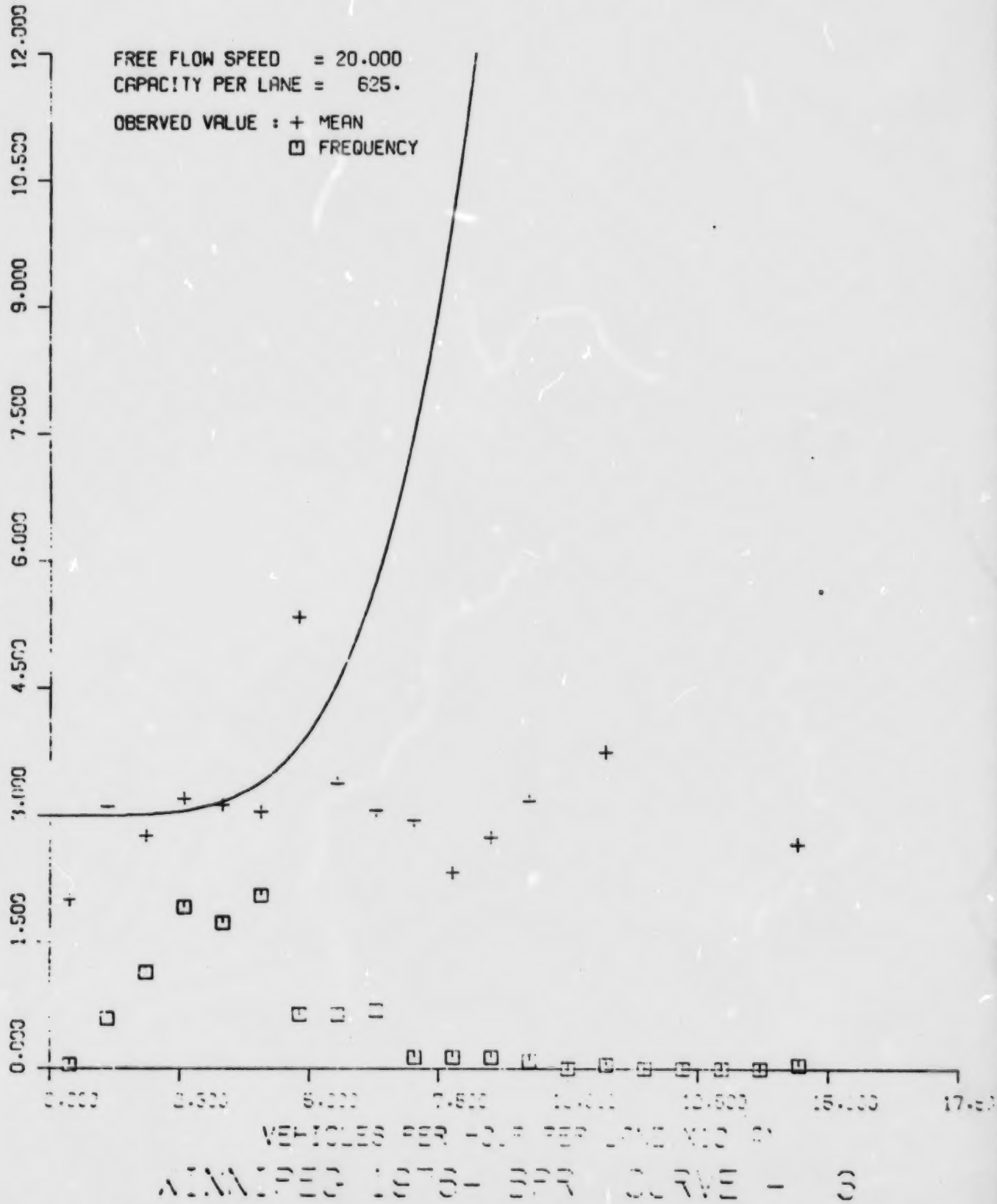


Figure 3.6 - Free Flow Speed Adjusted to 20.00 mph

LINKS WITH ABS DIFFERENCE BETWEEN OBS TIME (MINUTES) AND PREDICTED TIME (BPR CURVE), GREATER THAN 0.0 29/08/77

NO	NO	LENGTH	NULA	CACO	OBSERVED SPEED	OBSERVED VOLUME	OBSERVED MINS	BPR MINS (FROM OBS VOL)	DIFF	SUGGESTED CURVES CURVE	DIFF	CURVE	DIFF	CURVE	DIFF
428	427	2.53	1.0	10	55.0	14	2.76	3.67	-.91	13 17	-.91 -.00	15 18	-.91 -.00	16	-.00
437	474	1.29	1.0	10	36.9	510	2.10	2.31	-.21	9	-.11	14	.19		
516	515	1.30	2.0	10	47.0	257	1.66	1.88	-.22	14	-.22	15	-.22		
225	226	.61	2.0	14	18.5	1099	1.98	.92	1.06	3 7	-.75 .85	4 8	.29 .78	5	.47
243	244	.95	1.0	14	38.0	288	1.50	1.38	.12	9	-.12				
249	229	.30	2.0	14	27.3	683	.66	.44	.22	NONE					
338	337	.30	2.0	14	28.6	1007	.63	.44	.19	NONE					
340	343	.81	2.0	14	25.7	597	1.89	1.18	.71	3 6 9	-.62 -.17 .51	4 7	-.23 .36	5 8	-.06 .39
413	415	.80	2.0	14	22.4	105	2.14	1.16	.98	2 5 8	-.69 .22 .66	3 6 9	-.26 .54 .78	4 7	.05 .66
418	417	.41	2.0	14	41.7	625	.59	.60	-.01	NONE					
432	433	.54	2.0	14	30.3	1001	1.07	.80	.27	5	-.25	7	-.15		
433	479	1.13	1.0	14	37.7	284	1.80	1.64	.16	9	-.12	10	.14		
434	433	.64	2.0	14	32.3	884	1.19	.94	.25	7	-.14	8	-.02		
435	436	.23	2.0	14	27.1	885	.51	.34	.17	NONE					
475	474	.44	1.0	14	41.9	178	.63	.64	-.01	NONE					
477	478	1.00	1.0	14	31.4	357	1.91	1.45	.46	7 10	-.02 .41	8	.05	9	.21
479	433	1.13	1.0	14	29.4	477	2.31	1.66	.65	5 9	-.45 .38	7 10	-.15 .40	8	.15
742	741	.95	1.0	14	34.1	136	1.67	1.38	.29	6 9	-.26 .06	7 10	-.09 .29	8	-.09
742	743	.45	1.0	14	19.9	282	1.36	.65	.71	2	-.59	3	-.02		
1035	397	.59	2.0	14	21.6	316	1.64	.86	.78	2 5	-.50 .22	3 6	-.13 .43	4	.10

Figure 3.7 - Link Time Difference for Different Curves

links on a route basis. Links with large differences between predicted and observed times were plotted on a map in order to determine the links of an avenue or street that had to be reclassified. In some cases the number of lanes was corrected as well. This analysis also resulted in the correction of some observed travel times and volumes. In total, 159 links were reclassified, the number of lanes was changes for 23 links, the observed time updated for 192 links and the observed volume updated for 21 links.

The results of the recalibration and reclassification can be seen in Figure 3.7 which compares the time computed from the observed volume using the delay curve, the 'predicted time' and the observed time.

4. CALIBRATION AND VALIDATION OF THE ROAD NETWORK ASSIGNMENT

The calibration of the road network was achieved by comparing the observed link volumes with the link volumes predicted by the traffic assignment model. The comparison is performed by using the programs FPLOTR and manually, bu comparing screen line totals for the observed and predicted flows. Discrepancies between observed and predicted values may be caused by the errors introduced in the total auto O/D matrix or by improper coding of the road network. Since the 1976 road network differs little from the 1971 network which was very carefully calibrated, the corrections necessary to the coding of the road network were all found during the re-calibration of the volume-delay curves and most of the adjustments made involved the total auto O/D matrix.

This matrix is calculated from the total person work trip matrix by using the observed modal split and car occupancy matrices and a set of adjustment factors that serve to add other purpose trips and truck trips; that is

$$g_{pq} = \frac{g_{pq} * r_{pq}}{\gamma_{pq}} * f_{pq}$$

where (p,q) is an origin-destination pair of zones

g_{pq} is the total person work trips between p and p

r_{pq} is the proportion of trips by automobile

γ_{pq} is the auto occupancy

f_{pq} is the factor for other trips and truck trips

The factors f_{pq} are given as a matrix of values for 10 groups of zones (super zones) as indicated in Figure 4.1. The essence of the calibration procedure was a trial and error process that was aimed at finding the most

WORK TRIP TO TOTAL TRIP EXPANSION FACTORS

FACTOR 4

1976 A.M PEAK VEHICLE TRIPS

O \ D	0	1	2	3	4	5	6	7	8	TOL
0	1.56	1.90	1.50	1.43	1.55	1.43	1.43	1.50	1.50	1.50
1	1.09	1.44	1.09	1.09	1.02	1.05	1.09	1.05	1.09	1.09
2	1.05	1.45	1.10	1.10	1.02	1.10	1.10	1.10	1.10	1.10
3	1.06	1.34	1.06	1.06	1.02	1.05	1.06	1.05	1.06	1.06
4	1.14	1.51	1.14	1.14	1.02	1.10	1.14	1.10	1.14	1.14
5	1.02	1.29	1.02	1.02	1.02	1.05	1.02	1.05	1.02	1.02
6	1.01	1.01	1.01	1.01	1.02	1.01	1.01	1.01	1.01	1.01
7	1.35	1.65	1.25	1.25	1.02	1.30	1.25	1.30	1.25	1.25
8	1.15	1.51	1.10	1.10	1.02	1.10	1.10	1.15	1.10	1.10
TOL	1.09	1.44	1.09	1.09	1.02	1.05	1.09	1.05	1.09	1.09

Figure 4.1

appropriate factors based on the comparison of observed and predicted link volumes. While carrying this out 19 errors in the observed link volumes were detected and corrections were made by the staff of the City of Winnipeg.

All the factors in the calibration procedure were determined by the staff of the City of Winnipeg by using screen line counts. The screen lines chosen divide the city into three quadrants by using the natural geographic subdivision of the rivers. A specially written program entitled CORRD4 selects the links that cross each of these lines and provides the observed and predicted volumes, as shown in Figure 4.2, which are then totaled for each screen line. Figure 4.3 shows these totals.

First, an assignment was produced by using only the auto work trip matrix which is obtained by setting $f_{pq} = 1$. By relating super zone pairs with screen line crossings it is possible to adjust the various factors to increase or decrease the interchanges across the screen lines. The correspondence is as follows:

Quadrant	Super zones
1	1,2,3
2	4,5
3	Rest + downtown (0)

Various other considerations were taken into account in determining the factors f_{pq} such as the low production of truck trips by residential areas and high production of truck trips by industrial zones.

Another means to analyse the relation between the predicted and observed link volumes is given by the program entitled EPLOTR which plots the

EMME WINNIPEG 1976 AM PEAK
FIXED DEMAND (5ZONE GROUPS)

ROAD TRAFFIC ASSIGNMENT
CORRIDOR OUT2

LINK	FROM	TO	LENGTH (MILES)	TYPE	FREE FLOW (MPH)	CAPACITY (VEH/HR)	OBSERVED TIME (MINS)	OBSERVED VOLUME (VEH/HR)	PREDICTED SPEED (MPH)	TRAVEL TIME (MINS)	AUTO VOLUME (VEH/HR)	LANES	BUS VOLUME (VEH/HR)
1	355	885	.16	4	25.00	2625.	.36	2769.0	12.22	.79	2744.9	3.0	34.9
2	356	270	.27	4	25.00	1750.	.54	1158.0	21.55	.75	1234.2	2.0	28.9
3	358	925	.32	4	25.00	1750.	.82	1999.0	7.89	2.43	2120.4	2.0	22.5
4	362	1011	.13	4	25.00	1750.	.30	1986.0	6.18	1.26	2255.6	2.0	27.0
5	380	306	.42	9	35.30	2500.	.77	670.0	35.23	.72	765.6	2.0	12.0
6	423	325	2.15	15	41.40	2500.	2.28	481.0	41.40	3.12	446.1	2.0	0.0
7	450	628	.46	4	25.00	2625.	1.32	2183.0	22.12	1.25	1868.2	3.0	12.0
8	459	760	.39	9	35.30	3750.	.71	3081.0	22.62	1.03	3313.6	3.0	15.0
9	489	835	1.16	15	41.40	2500.	1.26	395.0	41.40	1.68	446.4	2.0	0.0

Figure 4.2

WT/TT COMPARISON

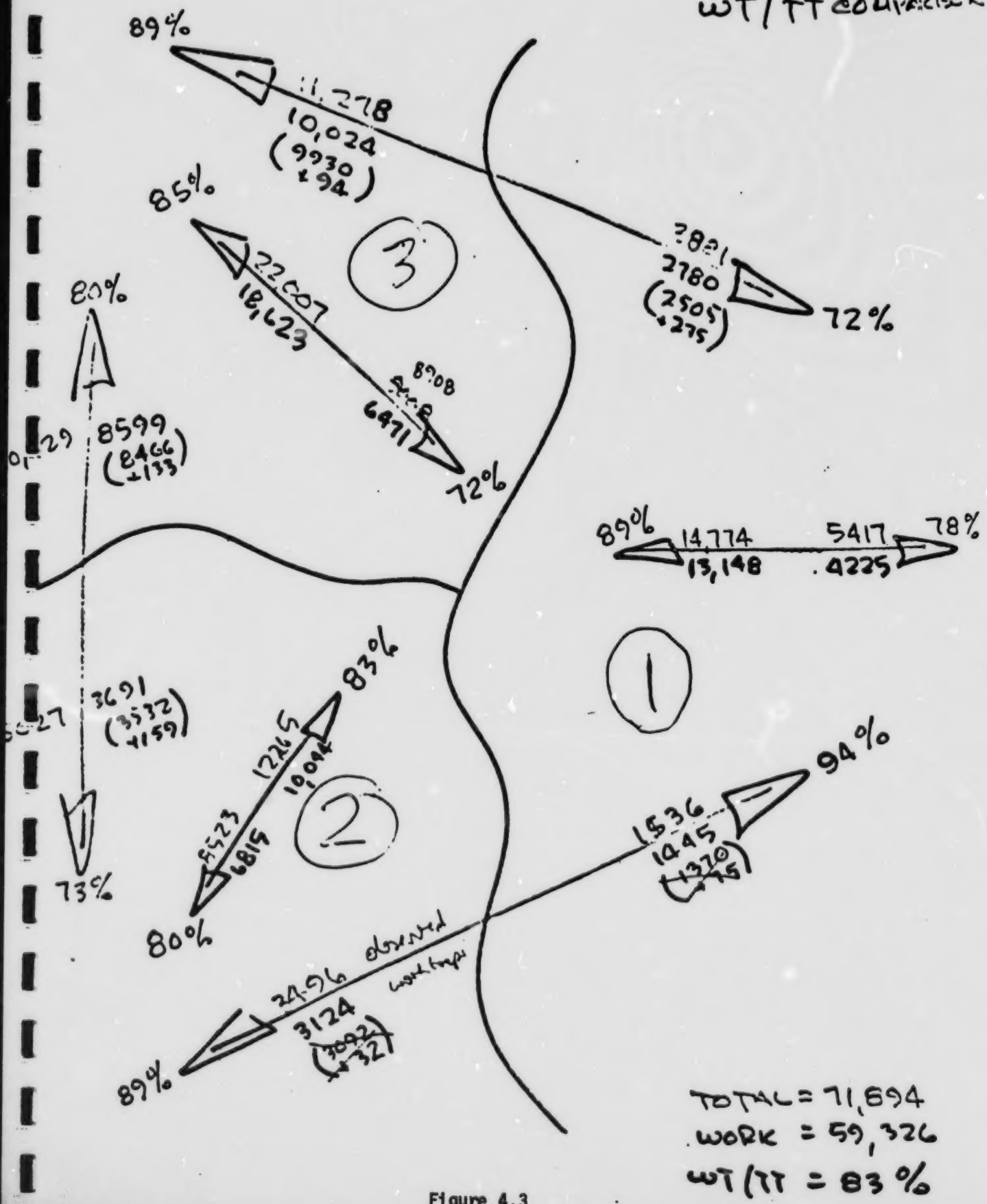


Figure 4.3

predicted against observed link volumes and link travel times. See Figures 4.4 to 4.6. This program also produces an exception report which lists the links for which the predicted and observed times differ by more than 1 minute, as shown in Figure 4.7.

The first set of factors used was denoted 4, and are those obtained in the 1971 calibration. During the calibration, factors 5, 6, 7 and 8 were used and for each, a road assignment was produced. (Two separate assignments were made for factor 7 since some changes were made to the total person trip matrix.) Figure 4.4 to 4.6 correspond to the results obtained with factor 8.

For archival purposes we list in Appendix 3 the factors 4, 5, 6, 7 and 8.

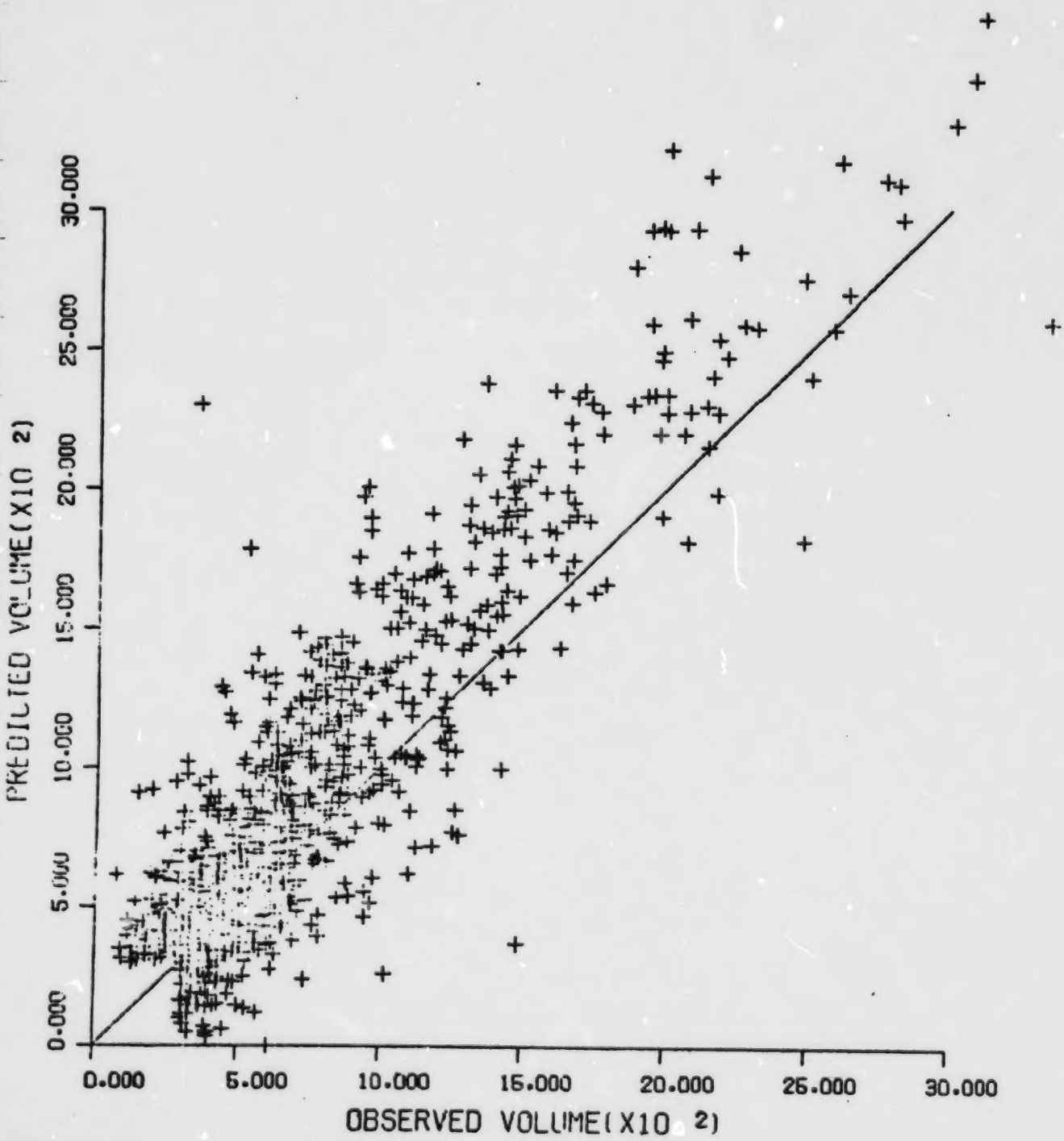


Figure 4.4 - Assignment using Factor 8

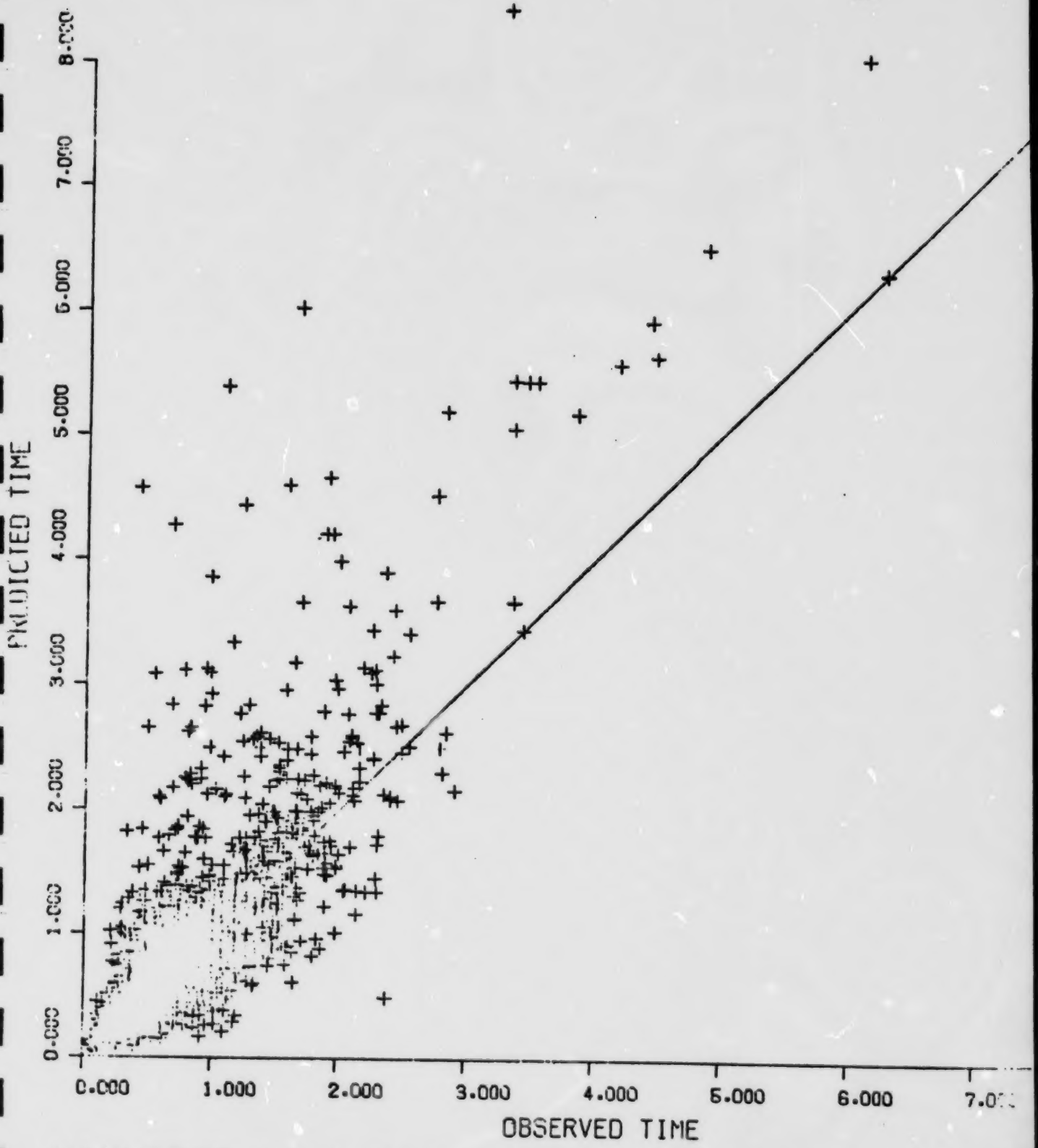


Figure 4.5 - Assignment uring Factor 8

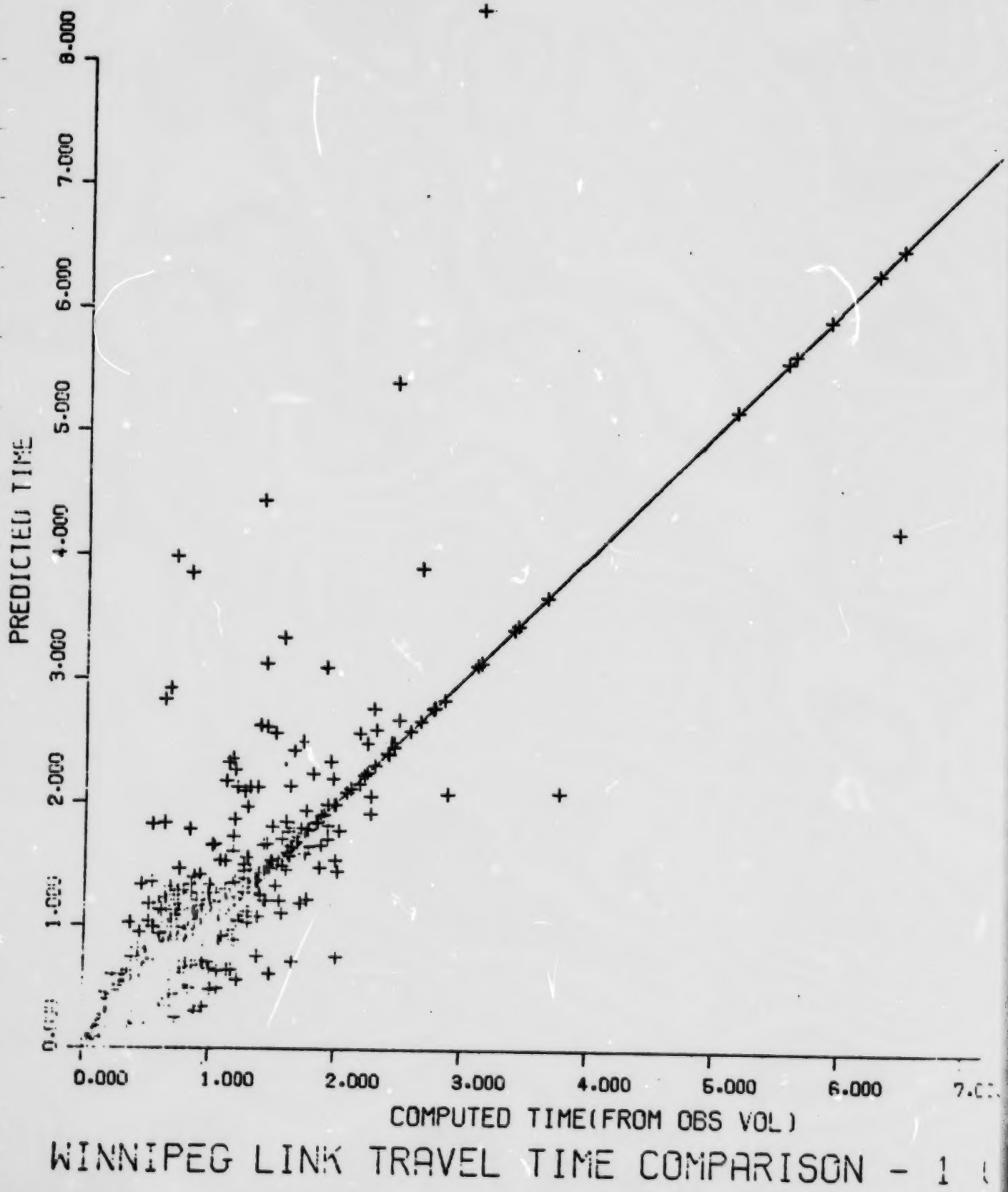


Figure 4.6 - Assignment using Factor 8

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] SPEED	[illegible] VOLUME	[illegible] TRAVEL TIME	PREDICTED TRAVEL TIME	COMPUTED TRAVEL TIME(FROM OBS VOL)
163	527	.75	1.	4	0.0	1132.	1.89	4.20	6.46
367	[illegible]	.25	2.	3	0.0	1326.	.81	2.62	1.40
[illegible]	[illegible]	.55	3.	[illegible]	[illegible]	[illegible]	1.32	2.56	1.51
527	163	.75	1.	2	0.0	603.	2.63	5.18	8.29
187	188	.24	1.	2	0.0	77.	.58	2.63	.63
224	214	.53	1.	3	0.0	242.	1.24	4.43	1.[illegible]
266	265	.3[illegible]	1.	3	0.0	479.	1.25	2.26	1.19
441	442	.59	2.	7	0.0	806.	1.53	2.36	1.18
655	658	.45	2.	2	0.0	757.	.98	3.09	1.92
722	7[illegible]	.2[illegible]	4.	7	0.0	3363.	.21	.75	2.[illegible]1
771	7[illegible]	.2[illegible]	2.	3	0.0	950.	2.[illegible]	3.79	.71
777	775	.47	2.	4	0.0	1466.	.95	3.12	1.44
788	785	.36	2.	7	0.0	530.	.99	2.92	.67
812	[illegible]	.32	1.	3	0.0	1[illegible]	.98	3.45	.84
817	815	.[illegible]	1.	3	0.0	6[illegible]	2.47	2.[illegible]	3.76
813	811	.47	4.	7	0.0	2145.	.91	2.33	1.14
680	7[illegible]	.97	1.	3	0.0	333.	2.36	3.69	2.06
571	575	.1[illegible]	1.	2	0.0	332.	1.10	3.33	1.57
41[illegible]	419	.41	1.	2	0.0	319.	1.35	2.61	1.44
445	455	.14	2.	3	0.0	979.	.71	1.43	.64
452	451	.27	2.	3	0.0	1147.	.69	2.17	1.13
461	45[illegible]	.3[illegible]	2.	[illegible]	0.0	2250.	1.10	5.39	2.45
69[illegible]	6[illegible]	.15	2.	7	0.0	1342.	.33	1.33	.54
802	711	2.[illegible]7	1.	16	0.0	525.	3.30	8.41	3.10

Figure 4.7 - Assignment using Factor 8

5. TRANSIT NETWORK VALIDATION AND CALIBRATION

Introduction

This part of the project required considerable effort since the City of Winnipeg did not have, prior to this study, a transit network model and the work included the definition of the network, its coding, validation and calibration.

The purpose of the validation and calibration is to make sure that the transit system is described properly. As it has been pointed out in the coding manual, the coded network must represent adequately all the possible passenger movements on one hand and the transit vehicle movements on the other hand. The validation of the network consists then of ensuring that the coding rules have been followed correctly and that the representation of the two types of movements is satisfactory. The tools used in validation are:

- the EMME data bank programs which perform the syntactic and data consistency checks
- the network generation programs which ensure that the rigorous restrictions imposed on the input data in order to realise the interface with the road network and to determine transit travel times are satisfied
- graphical displays of the network
- manual checks of the data
- analysis of the complete print out of a transit assignment.

We shall now review all the stages of the validation of the Winnipeg transit network.

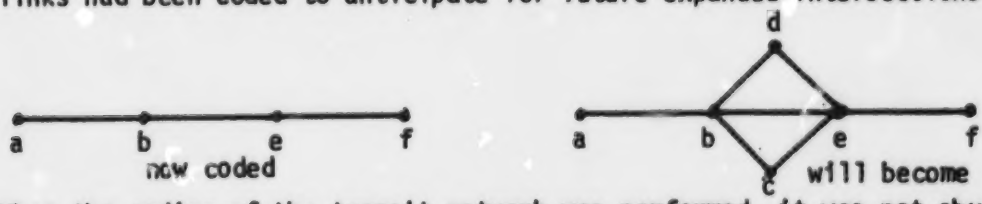
The transit network that describes the AM peak services has been coded by the City of Winnipeg staff by using the following EMME coding forms:

- TRANSIT LINE
- TRANSIT NODE - ROAD NODES CORRESPONDENCE
- TRANSIT LINK (for transit-only links)
- TRANSIT ACCESS LINK (see Appendix 4)

Stage 1

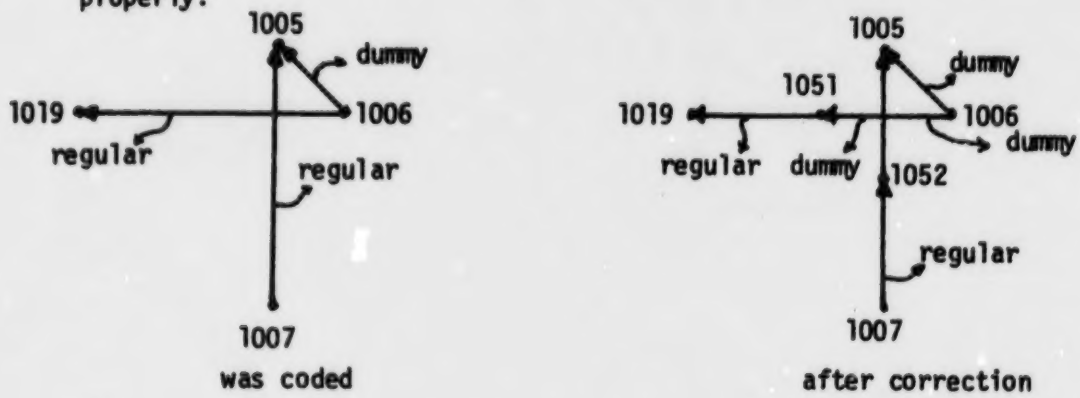
By the end of May 1977 the above data were submitted to the data bank validation modules. The following errors were detected:

- For many of the lines, the itinerary contained "turning" road nodes which are used to describe expanded road intersections and which must not appear on a line itinerary. We discovered that the problem came from the coding of the road network. In most of the cases, intersection crossing links had been coded to anticipate for future expanded intersections:



When the coding of the transit network was performed, it was not obvious for the analysts that nodes b and e were "turning" nodes. The problem was solved by replacing the two turning nodes by a transit-only node on the line itineraries. Those nodes were also entered in the correspondence table.

In other cases, the itinerary contained only one "turning" road node. Here, the expanded intersection did exist but it had not been coded properly:



The road intersection was corrected as shown above and a transit-only node with its corresponding nodes was introduced.

- A transit-only link (2166-755) had been coded but node 2166 did not appear on the itinerary of any line. After inspection, it was decided to delete that link.

- In the correspondence table, two express nodes corresponded to a single "turning" node. Here again the problem was related to future expanded intersections.

- Two unnecessary express nodes were also discovered and removed from the data.

At the same time, a visual analysis of the coded data permitted to discover that line 53 which runs only in-bound had not been coded properly. In fact, the out-bound itinerary must be coded as a single transit-only link with a very large travel time (600 min.)

Stage 2

After stage 1, the data were consistent. We then performed a run of the transit network generation module which achieves the interface with the road network. The interface could not be realised on a road artery which was coded as two one-ways. In that case, the expanded intersections consisted of six "turning" nodes. In the transit coding, two transit-only nodes, corresponding respectively to three of the "turning" nodes, had been coded for each intersection. The solution was to remove one of the two transit nodes and to make the other correspond to the six "turning" nodes.

Stage 3

The next run of the network generation module printed out twelve pages of warning messages which are divided in three categories:

1. 51410I CANNOT ESTABLISH CORRESPONDENCE WITH ROAD LINK
   AN INTERMEDIATE ROAD NODE MAY BE MISSING
   LINE: iii LINE NAME
   LINK: nnn , m m m
   ABOVE LINK TREATED AS TRANSIT-ONLY LINE SECTION

2. 51440I INTERSECTION-CROSSING LINK RESERVED FOR TRANSIT VEHICLES ONLY
   LINE: iii LINE NAME
   LINK: nnn , m m m

3. 51505I (n n n , m m m) MAY BE AN UNKNOWN TRANSIT-ONLY LINK

Message 1 is printed when the program cannot identify which of the "turning" nodes is used to enter or leave an expanded intersection. This situation occurs if an intermediate road note that precedes or follows the intersection

has been omitted. In that case the node will have to be inserted on the line itinerary. It may also be that the intersection is arrived to or left from by a transit-only link. In that case, it is not an error but the transit-only link should be defined in the transit-only link data.

Message 2 is printed when the two "turning" nodes are identified, but the corresponding dummy road link does not exist. Such a situation occurs in the case of "no left turn except for buses". A transit-only link must then be defined.

Message 3 is printed when the program does not find link (nnn , mmm) in the transit link data. (nnn , mmm) may then be a line section consisting of more than one transit-only link and in that case all the transit-only links of the section must be defined.

One "left turn for buses" was detected by the program. An analysis of the itinerary showed that it was correct but that the corresponding transit-only link had not been defined.

More than 50 transit-only links had been omitted in the coding of the network. In a few cases, problems which seemed related to transit-only links were in fact caused by wrong node directions, which were then corrected.

Stage 4

After the above corrections were made, a graphical display of the network was produced. We then discovered that two centroids were not linked to the network and also realised that there was no access to the dummy express

nodes. It had been assumed by the analysts that the access to the corresponding node would be used, which was wrong.

By that time, the bus/auto travel time model had been developed. Since relationships were related to line types, we entered the line types in the data bank.

Stage 5

After all these further modifications were made, the network generation program was run and the complete output was sent to the staff of the City of Winnipeg. They then inspected carefully all the following elements:

- the access links
- the characteristics of each line
- the list of all the lines passing at each node
- the list of road nodes not used by transit
- the itinerary of each line

The analysis resulted in the following corrections:

- change an access link to centroid 10
- modify the itinerary of lines 30, 48, 53
- on line 41, replace a few express nodes by their corresponding road node (to permit transfers)
- change the type of line 44 to "express"
- change the headway on line 5

Stage 6

At that point in time we were ready to perform a transit assignment. The output of the assignment and a print out of transit paths between selected O-D pairs were sent to Winnipeg. An analysis of the transit paths suggested

that the type of a few lines should be changed from "express" to "regular-fast". It was also decided to change the type of line 34 from "regular" to "regular-fast" in order to increase the predicted volumes. Headways on the "Dial-a-bus" service were reduced to 1 minute.

Once these changes were implemented the network was considered to be valid and we started the calibration process.

Calibration of the Transit Network

The calibration deals with the other aspect of the transit system, that is: the behaviour of the transit passengers in the selection of paths on the network. Given certain behaviour hypotheses, it is necessary to estimate the value of certain parameters of the transit path algorithm in order for it to produce satisfactory paths between the various O-D pairs.

The parameters to be estimated are:

- WFAC , a regularity factor relating the waiting time to the headway of the line to be boarded
- WMIN , the minimum waiting time
- WMAX , the maximum waiting time
- WAIT , the weight of waiting time used in the calculation of the impedance of a path in generalized time units
- WPEN , a constant penalty added to the impedance every time the passenger has to wait for the bus
- WALK , the weight of walking time (access-egress) used in the calculation of the impedance of a path.

A given path that contains n line sections, has an impedance in generalized time units, that is given by the expression:

$$IMP = WALK * (\text{access} + \text{egress time}) + WAIT * \sum_{\ell=1}^{n} w_\ell + \sum_{\ell=1}^{n} T_\ell + n * WPEN$$

where

- W_ℓ is the waiting time of the ℓth line defined as

  $W_\ell = \min [\max (WMIN, WFAC * HDW_\ell), WFAC * HDW_\ell, WMAX]$

- HDW_ℓ is the headway of the ℓth line and transfer time is considered as being included in waiting time.

- T_ℓ is the in-vehicle time spent on the ℓth line, which is assumed to have a weight of 1.0 in the impedance calculations.

For each O-D pair the algorithm selects the path with minimum impedance from origin O to destination D. The best way to calibrate the transit model would be to compare the predicted paths to the actual paths obtained from the O-D survey. Unfortunately, in the Winnipeg survey there was no question concerning the path used by transit riders. The method which we used consisted in analysing the predictions of a transit assignment, obtained with the observed O-D matrix by comparing it with the observed volumes on the segments and an occasional reevaluation of the observed transit O-D matrix. The analysis was made on level of service statistics (like mean total trip time, mean number of transfer, distribution of total trip time, etc.) and on predicted line volumes. Given the all-or-nothing aspect of the assignment, only large volumes may be analysed. We agreed with the staff of the City of Winnipeg to analyse the following volumes:

- the volume at the maximum load point of each line on both directions
- the location of the maximum load point
- volume profiles on lines
- screen line volumes
  - entering and leaving CBD
  - bridges
  - other high volume links

In the first stage of the analysis, three assignments were performed using the following parameters:

		WALK	WAIT	WFAC	WPEN	WMIN	WMAX
1	=	3.0	3.0	0.5	0.0	0.0	10.0
2	=	0.0	1.0	0.5	0.0	0.0	10.0
3	=	0.5	2.0	0.5	4.0	0.0	10.0

The analysis made by the staff of the City of Winnipeg showed that assignment number 1 was the best one but the split of volumes between competing lines was not satisfactory. We then introduced the "common line section" algorithm in the model. With this algorithm, the passengers are diverted over common bus lines proportionally to the frequency of each line (i.e. passengers are assumed to board the first line that arrives at the bus stop). We ran four new simulations with the following parameters:

		WALK	WAIT	WFAC	WPEN	WMIN	WMAX
4	=	3.0	3.0	0.5	0.0	0.0	10.0
5	=	0.0	1.0	0.5	0.0	0.0	10.0
6	=	0.5	2.0	0.5	4.0	0.0	10.0
7	=	0.5	3.0	0.5	4.0	0.0	10.0

Assignment number 4, which is similar to number 1, proved to be the best one and the spread of volumes had improved significantly. One point still remained unclear: the predicted transit volumes that were destined to the University of Manitoba were much higher than the observed (3148 compared to 1065). Considering the fact that the regular enrolment at the University of Manitoba was more than 14,000 students, Ed Guertin suggested that the observed volumes may have been under estimated and that they should be revised. On our side we suggested that the demand to University of Manitoba may have been over-estimated. The departure time codes used to determine the AM peak hour matrix are such that the trips destined to the CBD would cross the CBD area between 7:30 and 8:30. But the University is located relatively far to the south of the CBD and many of the AM peak trips would reach the University much later than 8:30 and thus would not be included in AM peak volume counts. The departure time codes were revised and a new O-D matrix was defined. The new volumes were now 2176 in the matrix and 1918 for the counts.

At the same time, the analysis of circuit times predicted by the bus time model had been completed and it was suggested that 14 route types should be changed.

A new simulation was made by using the parameters of assignment number 4 and the results were reanalysed. The analysis suggested that the type of line 42 should be changed from "express" to "regular-fast" because it seemed to have too high an attraction. Also, a few access links were deleted and a few were added.

The previous simulation was repeated with the above corrections made to the network. The staff of the City of Winnipeg then suggested that the calibration task was complete since they were highly satisfied with the results of the assignment.

We would like to conclude this section with the following observations concerning the transit system.

The network contains

- 56 lines
- 1755 line segments
- 575 regular road nodes used by transit
- 198 transit nodes
  - 80 = expanded intersections
  - 90 = transit-only nodes
  - 28 = express nodes
- 305 user defined transit-only links.

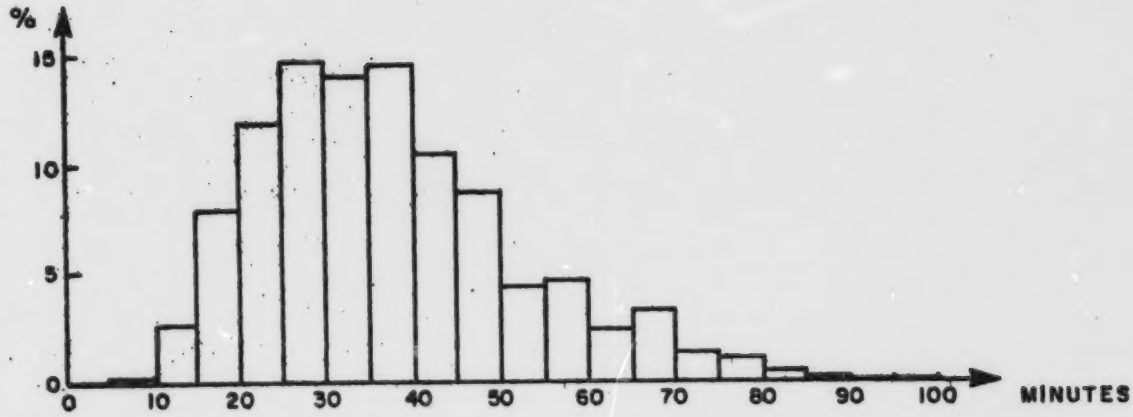
The total demand is 20 495 trips.

The mean trip time is 36.95 minutes

in-vehicle	≐24.01
wait	= 4.41
access-egress	= 8.53

and the mean number of line sections used for a trip is 1.68.

The distribution of total trip time is given by the histogram shown below.



The entire process of coding, validation and calibration required a total elapsed time of about one year.

6. CALIBRATION OF THE MODAL SPLIT FUNCTION

The O/D Survey

The basic data that was used for the calibration of the modal split function are the results of the O/D survey that was carried out by the City of Winnipeg in the spring and summer of 1976. The survey was carried out in large part by home interviews of a sample of 20% of households. The actual sample size obtained was roughly 17%, after refusals and rejects have been taken into account. In addition, a survey questionnaire to be returned by mail was distributed to the students of the three Winnipeg Universities; the effective sample of student trips was approximately 23%. The total sample, consisting of the individual detailed data, amounted to 52 424 questionnaires and this data was transmitted to us on a magnetic tape by the City of Winnipeg. Then, the 'departures codes' described in the introduction were applied in order to separate the trips that occur during the 7:30 - 8:30 AM peak. There were 17 761 individual records in the peak hour sub-sample. A detailed description of the data formats is given in Appendix 2.

The Impedance (Travel Time) Variables

The number of trips that occur during the peak hour were expanded by the proportion of the sample in each zone, that was calculated by the City of Winnipeg, in order to obtain the following Origin/Destination matrices:

- auto drivers and passengers (1) , auto drivers (1')
- transit passengers (2)
- total trips (3) = ((1) + (2))
- modal split (4) = ((1) / (3))
- car occupancy (5) = ((1) / (1'))

A summary by origin and destination of O/D Matrices (1) and (2) are given in Figures 6.1, 6.2, 6.3, 6.4, while an average of (4) by origin and destination is given in Figures 6.5 and 6.6. (The auto drivers and passengers O/D matrix, shall be refered to as the auto O/D Matrix) The auto O/D Matrix was scaled by the appropriate factor to obtain the total auto O/D Matrix and this last was assigned to the road network by using the equilibrium traffic assignment of EMME. The resulting origin to destination travel times constitute the O/D matrix of

- road travel times (6)

and by tracing a set of shortest paths on the links that carry flow we obtain the O/D matrix of

- distance by road (7)

Next, the transit O/D Matrix was used to calibrate the transit assignment. Other than refinements of the transit network representation, this calibration determines the coefficients of generalized time (or cost) in the expression

$$\text{Transit impedance} = \alpha\,(\text{Access Time} + \text{Egress Time} + \text{Wait Time}) + \beta\,(\text{In Vehicle Time})$$

As described earlier the values for α and β, determined in cooperation with the City of Winnipeg, are 3 and 1 respectively. Thus we obtained

WINNIPEG 1976 OBSERVED DEMAND (1 = 10 TRIPS)

AUTO DEMAND BY ORIGIN

Figure 6.1

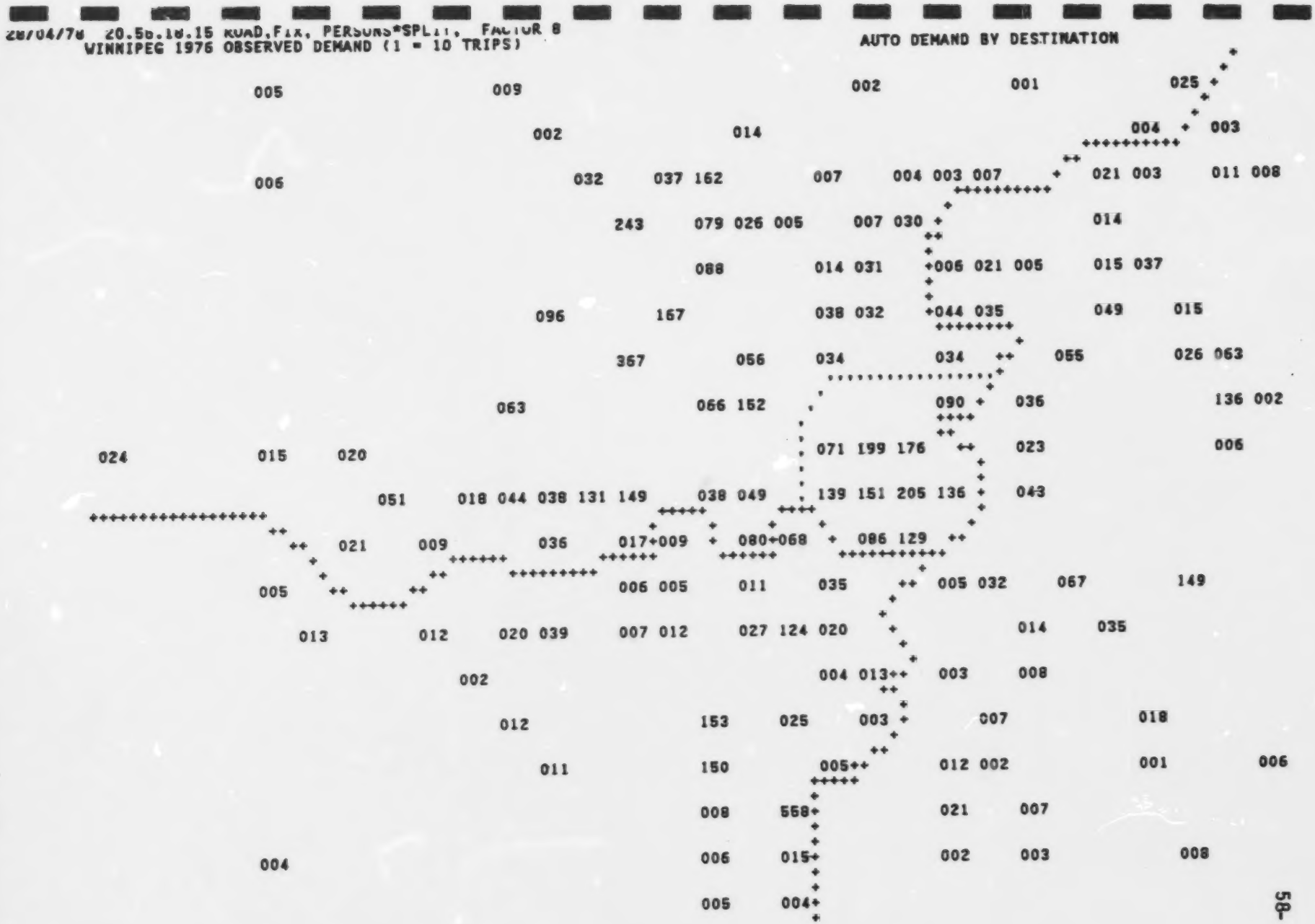

28/04/78 20.56.18.15 ROAD,FIX, PERSONS*SPLIT, FACTOR 8
WINNIPEG 1976 OBSERVED DEMAND (1 = 10 TRIPS)
AUTO DEMAND BY DESTINATION

Figure 6.2

02/05/78 17.01.13. 4 TRANSIT,FIX, NEW O-D (ZONE 59) COMMON L
WINNIPEG 1976 OBSERVED DEMAND (1 = 10 TRIPS)

TRANSIT DEMAND BY ORIGIN

Figure 6.3

WINNIPEG 1976 OBSERVED DEMAND (1 = 10 TRIPS)
TRANSIT DEMAND BY DESTINATION

Figure 6.4

02/05/78 17.01.13. 4 TRANSIT,FIX, NEW O-D (ZONE 59) COMMON L 28/04/78 20.56.18.15 ROAD,FIX, PERSONS*SPLIT, FACTOR 8
WINNIPEG 1976 OBSERVED DEMAND
MODE SPLIT BY ORIGIN

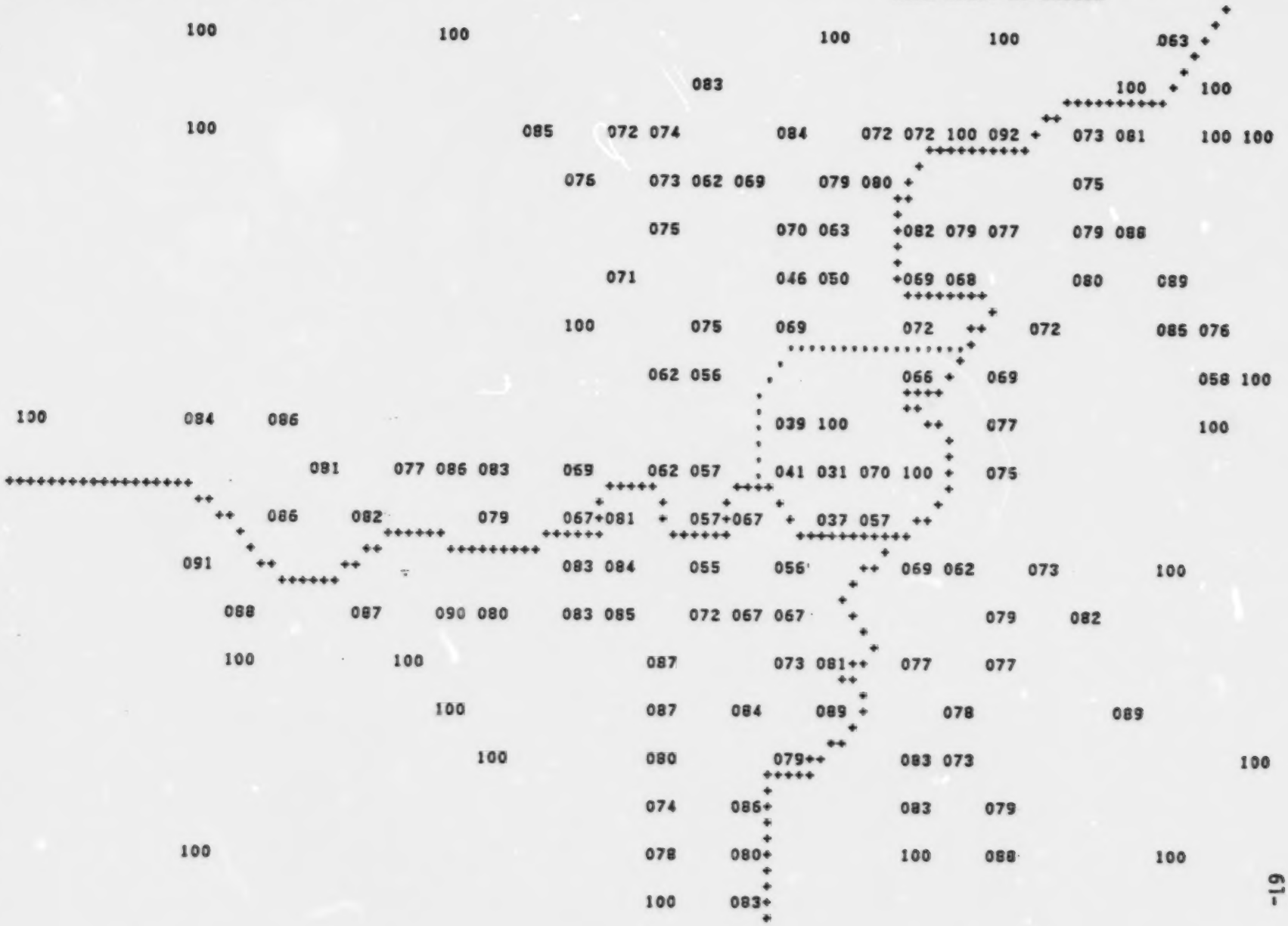


Figure 6.5

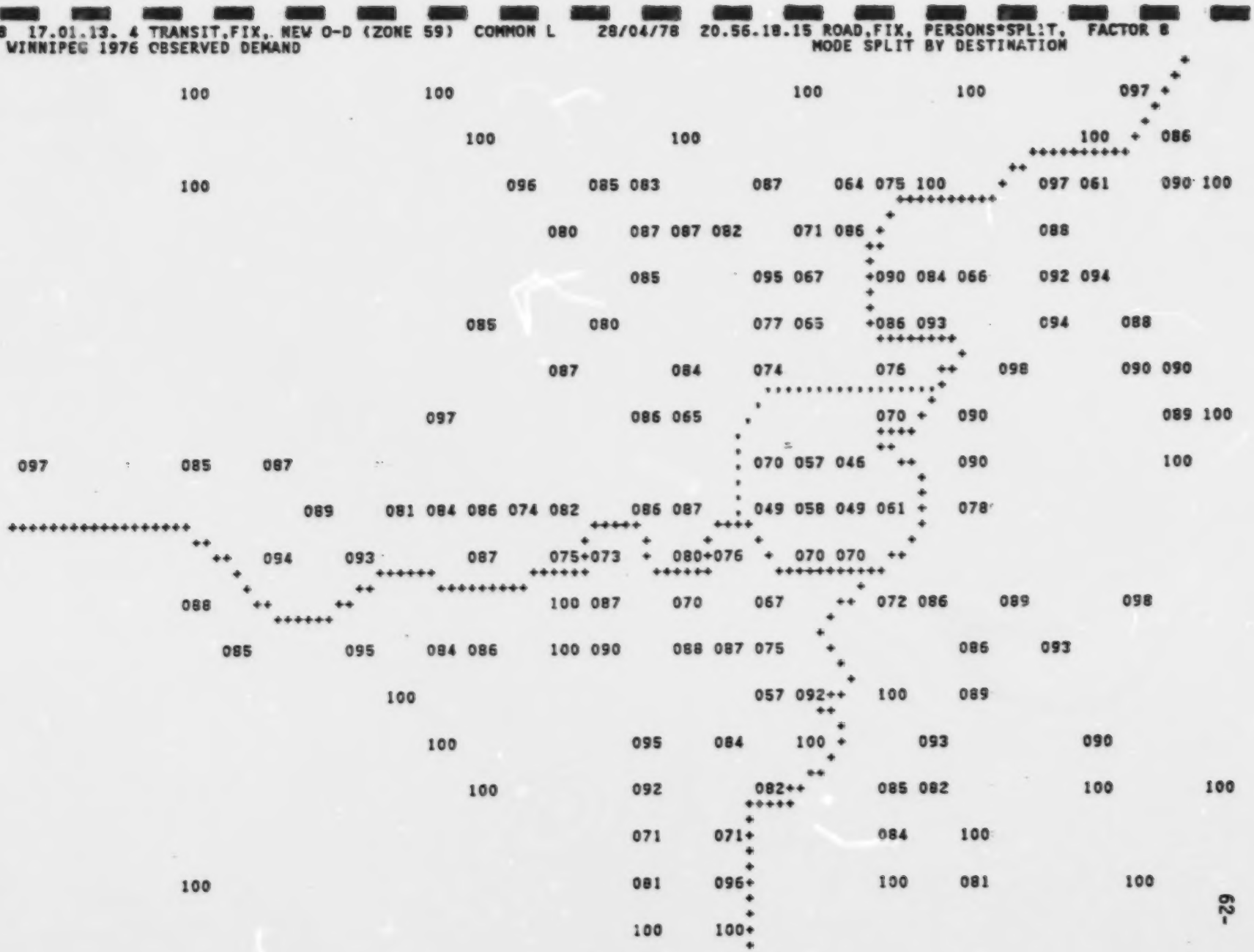

02/05/78 17.01.13. 4 TRANSIT,FIX, NEW O-D (ZONE 59) COMMON L 28/04/78 20.56.18.15 ROAD,FIX, PERSONS*SPLIT, FACTOR 8
WINNIPEG 1976 OBSERVED DEMAND
MODE SPLIT BY DESTINATION

Figure 6.6

the O/D Matrix of

. transit impedance (8)

and by tracing the shortest paths used we determined the O/D Matrix of

. No. of transit transfers (9)

The Socio-Economic Variables

Since our approach is to calibrate a zonal aggregate modal split function, we extracted from the survey data the average car ownership/household/zone, the proportion of new traveling at the peak hour and the proportion of students traveling at peak hour for each O/D pair.

The other socio-economic variables were obtained by the City of Winnipeg from various sources and transmitted to us. The Statistics Canada 1976 Census served to obtain the average income/household/zone and the O/D survey served to estimate the number of jobs/zone. The parking costs month/zone were evaluated by using 1971 data and the number of parking space/job/zone was evaluated using 1971 data as well.

Thus, il all, a file was constructed that consisted of the dependent variable, the modal split, and the independent explanatory variables outlined above. This file contained the records for all O/D pairs that had more than 60 trips by both modes in the expanded matrix (3) of trips by both modes. The main reason for adopting this procedure is that the modal split for O/D pairs with smaller demand would have far more variability due to the relatively small number of trips in the sample.

The Functional Form of the Modal Split Function

The functional form that we chose for the calibration is that of the logistic function. Although this form achieved recent fame in its use as a disaggregate probabilistic multiple choice function, we use it with aggregate data due to its ease of manipulation and its property of predicting choice values with a smooth ogive type curve. The form that we used is

$$\rho_{au} = 1 / 1 + \exp (k_o + \sum_i k_i x_i)$$

where ρ_{au} is the proportion of trips that occur by car

k_o is a constant and

k_i , $i=1,\ldots,m$ are the coefficients associated with the

x_i , $i=1,\ldots,n$ explanatory variables.

A simple algebraic manipulation results in the form

$$\ln \left(\frac{1-\rho_{au}}{\rho_{au}}\right) = k_o + \sum_i k_i x_i$$

which is used for calibrating k_o , k_i , $i=1,\ldots,n$ by simple linear regression. This method of estimation is often referred to as Berkson-Theil estimation to acknowledge their early work[1,2] with aggregate logistic function calibration.

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1 Berkson, J., "Maximum likelihood and minimum x^2 estimate of the logistic function", Journal of American Statistical Association 50, pp. 130-161, 1955.

2 Theil, H., "Principles of Econometrics", pp. 65-76, Wiley, New York, 1971.

Another functional form that we tried is the so-called 'dogit' proposed recently by Gaudry[3] which adds to the logit form modal constants θ_{au}, θ_{tr} as follows:

$$\rho_{au} = \frac{1}{1 + \theta_{au} + \theta_{tr}} \left(\frac{1}{1 + \exp\left(k_o + \sum_i k_i x_i\right)} + \theta_{au} \right)$$

However, in only the trials that we performed, the best values for θ_{au}, θ_{tr} were always zero, that is the logistic function was satisfactory and neither of the two modes considered had a fixed proportion (θ_{au} or θ_{tr}) of the modal split as an advantage.

The actual calibration test spanned a period of light months during which several hundred regressions were run, by using also transformations of the explanatory variables. The best modal split model for all the considered O/D pairs is given in the following table:

Variables	Parameter Value	95% confidence interval	
Constant (k_o)	2.563	1.758	3.369
transit impedance	-0.0122	-0.0220	-0.00242
auto time	0.0220	0.00192	0.0422
proportion men	-3.279	-4.117	-2.441
parking cost	0.0745	0.0532	0.0957
car availability	-1.904	-2.726	-1.082
R^2	.60		
R	.77		

Table 6.1 - Model 1

3 Gaudry, M. and Dagenais, Marcel G., "The Dogit Model", publication #82, Centre de recherche sur les transports, Université de Montréal, 14pp. 1978.

We were not entirely satisfied with this model, in particular since the best fit obtained with a transformation of variables was not much better, as can be seen below

Variables	Parameter Value	95% confidence interval	
Constant (k_o)	16.566	10.000	-23.131
(transit impedance)^2	- 0.000758	- .000127	- 0.000242
(auto time)^2	0.000242	-0.000180	0.000665
(proportion men)^2	- 2.256654	-3.478	-2.234
parking cost	0.36340	0.276	0.444
ℓn (income)	- 1.752	-2.446	-1.058
R^2	.64		
R	.80		

Table 6.2 - Model 2

We proceeded then to subdivide the origins into subgroup by using a criterion related to the error introduced by the modal split function. We reasoned that, errors on individual O/D pairs were unavaidable, however the model should not distort the O/D Matrix, that is there should not be too much bias introduced on demand totals by origins and destinations. Thus, we subdivided the origins into subgroups according to the error introduced by the model on origin totals; that is, origins which had negative deviations were grouped together and similarly origins with positive errors and origins which had acceptable error formed a second and third subgrouping. Finally we obtained four modal split models as follows.

Parameter Values

Variables	Model 3a	Model 3b	Model 3c	Model 3d
Constant	2.352 (1.004 5.708)	1.516 (0.297 2.735)	3.071 (-0.0140 6.156)	2.935 (1.860 4.010)
transit impedance	-0.0133 (-.0532 0.0265)	-0.0101 (-.0221 0.00178)	-0.0315 (-0.0513 -0.0118)	-0.0139 (-0.0408 0.-131)
auto time	0.0334 (-.0503 0.117)	0.0253 (0.000186 0.0504)	0.0733 (0.0343 0.112)	0.0323 (-0.0302 0.0949)
proportion men	-2.799 (-.5.646 0.0491)	-3.719 (-4.827 -2.611)	-3.101 (-5.043 -1.159)	-2.499 (-4.020 -0.978)
parking cost	.0959 (0.0225 0.169)	.0968 (0.0694 0.124)	.0471 (0.00471 0.0895)	.0332 (-0.0124 0.0787)
car availability	-3.023 (-6.359 0.312)	-1.232 (-2.394 -0.0698)	-1.502 (-4.686 1.682)	-1.844 (-3.139 -0.548)
R^2	.72	.67	.78	.64
R	.85	.82	.88	.80
No. of O/D pairs	26	135	36	45

The numbers in parentheses are the 95% confidence interval for the values of the parameters.

Table 6.3

In summary, the calibration of the modal split function turned out to be much more difficult that we had anticipated, however we are now satisfied with the results.

7. BASE YEAR CALIBRATION - BI-MODAL MODEL

Introduction

The execution of a bi-modal assignment in EMME requires the simultaneous use of the vehicle assignment, the transit assignment and the modal split function. As described earlier in this report, each of these model is calibrated independently and then they are used jointly in the computations. Since each of these models introduces a certain error by its calibration it is certain that there will be some differences between the observed values and the output of the bi-modal computations for the base year. Fortunately, these differences are not large and are well within the variances which are acceptable in calibration of transportation models.

Results of the Base Year Calibration

The staff of the City of Winnipeg asked that we apply the modal split function to all the origin-destination pairs, even though we had calibrated the model by using only origin-destination pairs that had more than 60 trips in the expanded total trip matrix. This became necessary since only about 28% of the total trips were represented by that sample. Thus, we applied, to all origins that were not represented in the calibration data, the initial model split model (model 1). For all other origins, we applied the corresponding modal split models to all the relevant destinations. The results were surprisingly good. Only 307 trips, or .5% of the total number of trips, are the difference between the observed total number of trips by auto and the differences that result on trip ends, that is origin and destination totals, are mostly of the order of up to 8%.

Figure 7.1 illustrates the auto demand by origin for the base year. All origins that generate more than 500 trips during the peak hour are highlighted by the corresponding figure being enclosed in a rectangle. Figure 7.2 shows the relative demand difference as a fraction of the demand by origin. Except for origin zones 46 (0.22), 81 (0.13) and 80 (.17) all other differences are acceptable and do not exceed .10. Figures 7.3 and 7.4 show respectively the observed modal split by origin, with the rectangles again highlighting origins that have more than 500 trips, and the modal split predicted by the bi-modal model for the base year. Again, except for origins 46, 81 and 80 the calibration provides a very good fit to the observed modal split.

A similar analysis was carried out by destination. Figure 7.5 shows the observed demand by destination zone and Figure 7.6 the relative difference in demand by destination. The largest differences, for destinations of more than 500 trips are .13 for zone 147, and .11 for zone 47, while all other differences for the large zones are less than .10. Figures 7.7 and 7.8 give the observed and predicted modal split by destination.

We judged these demand differences acceptable in view of the general consideration that the 'true' demand varies daily and differences of the order of 10% between various days of the week are accepted to be common place. Further, these differences were not sufficiently high to materially change the orders of magnitude of the link flows on the important arteries.

The computing times and the corresponding costs on the CDC Cyber 176 of the Université de Montréal for the base year bi-modal run are as follows:

. Generate transit network	3.66
. Calculate bus frequency	1.23
. Calculate transit impedance	1110.55
. Initialize road traffic demand	3.44
. Perform road traffic assignment	2509.44
. Modify transit link times	67.61
. Calculate fixed transit demand	1.77
. Calculate demand function (transit)	0.00
. Perform transit assignment	423.91
. Modify transit capacity	0.00

Central Processor	$189.20
Input-Output	22.80
Fast Memory	560.40
	$772.40

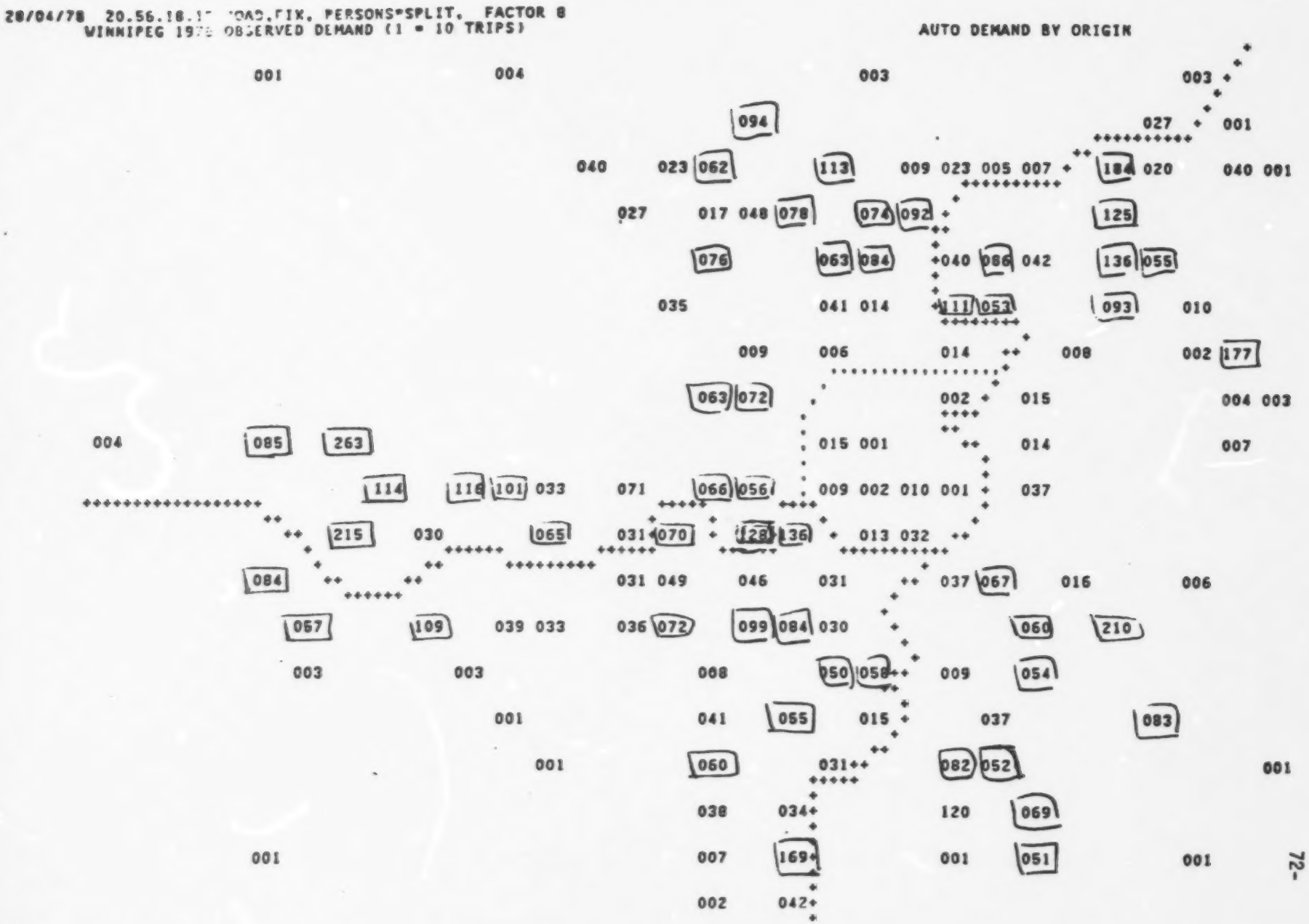

Figure 7.1 ☐ Origin demand larger than 500 trips

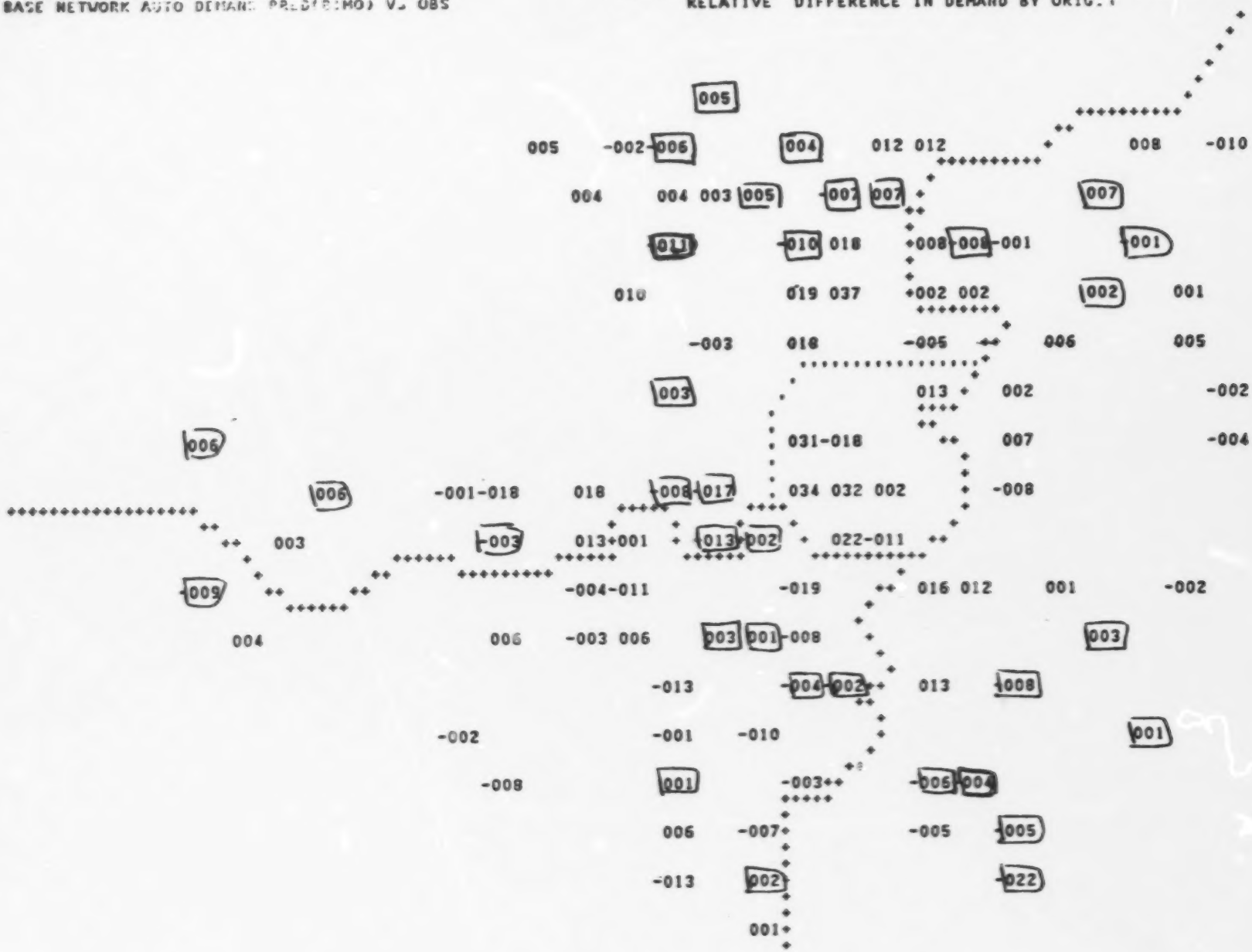

Figure 7.2 ☐ Relative difference in demand for origin larger than 500 trips

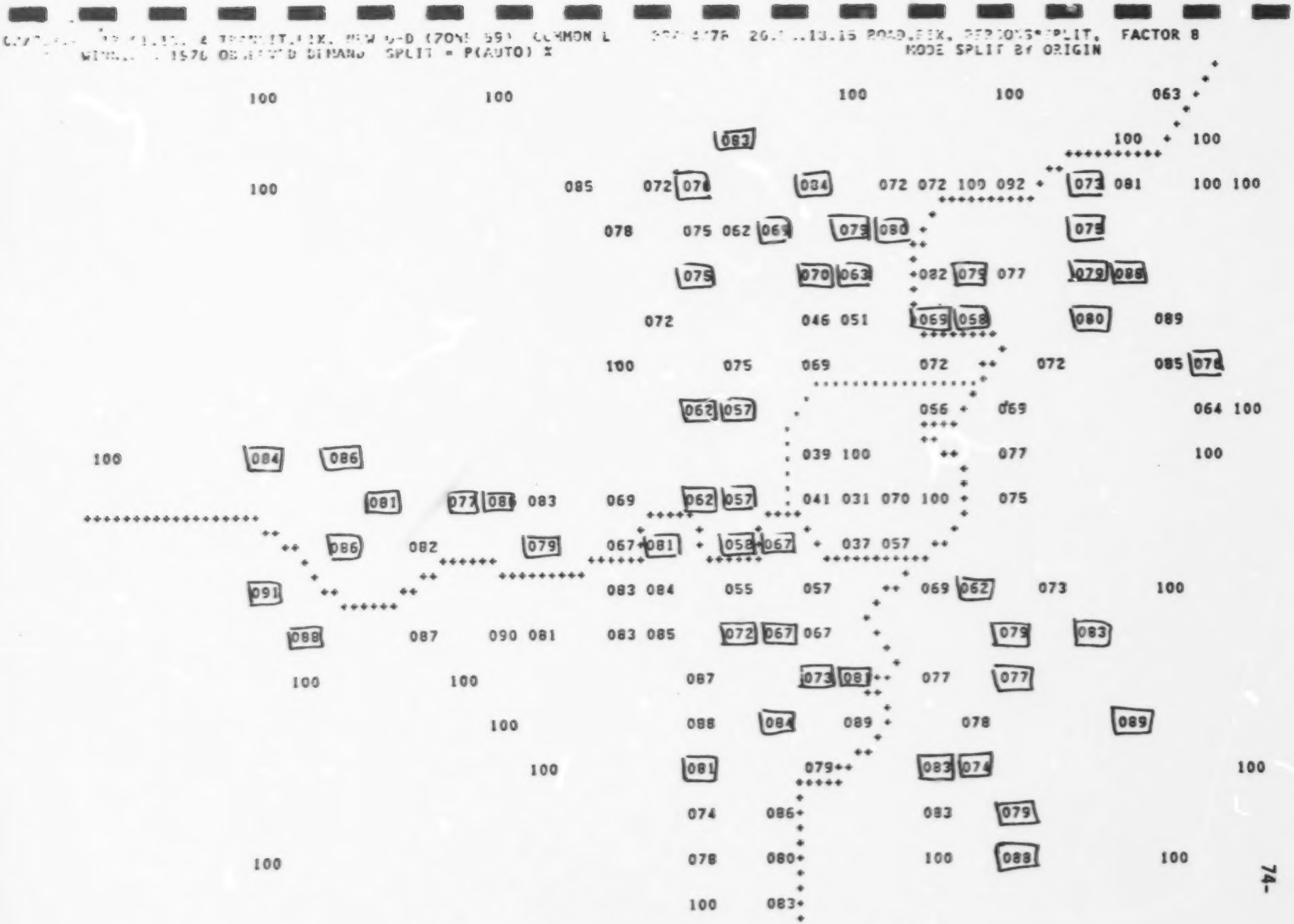

Figure 7.3 Origin demand larger than 500 trips

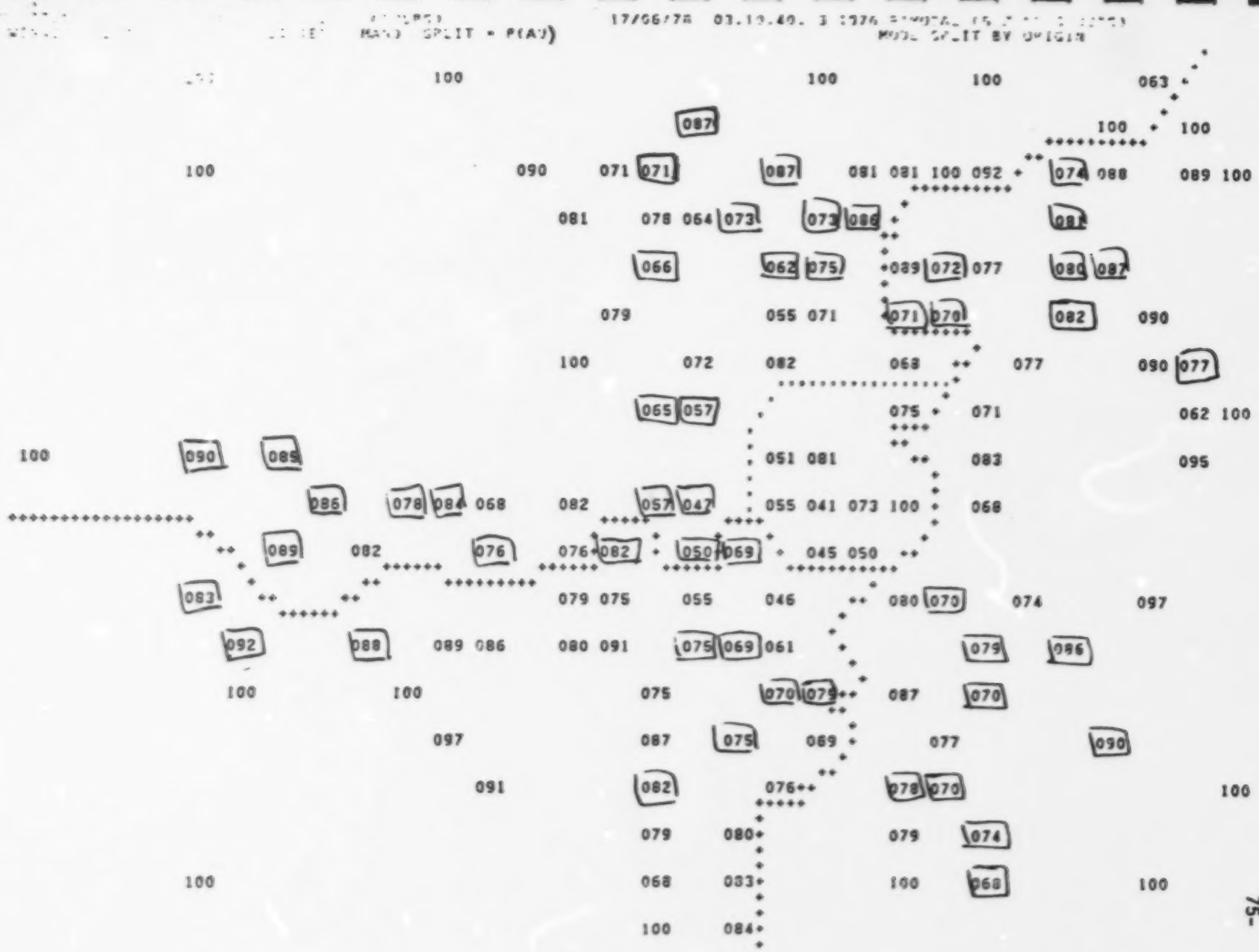

Figure 7.4 ▭ Origin demand larger than 500 trips

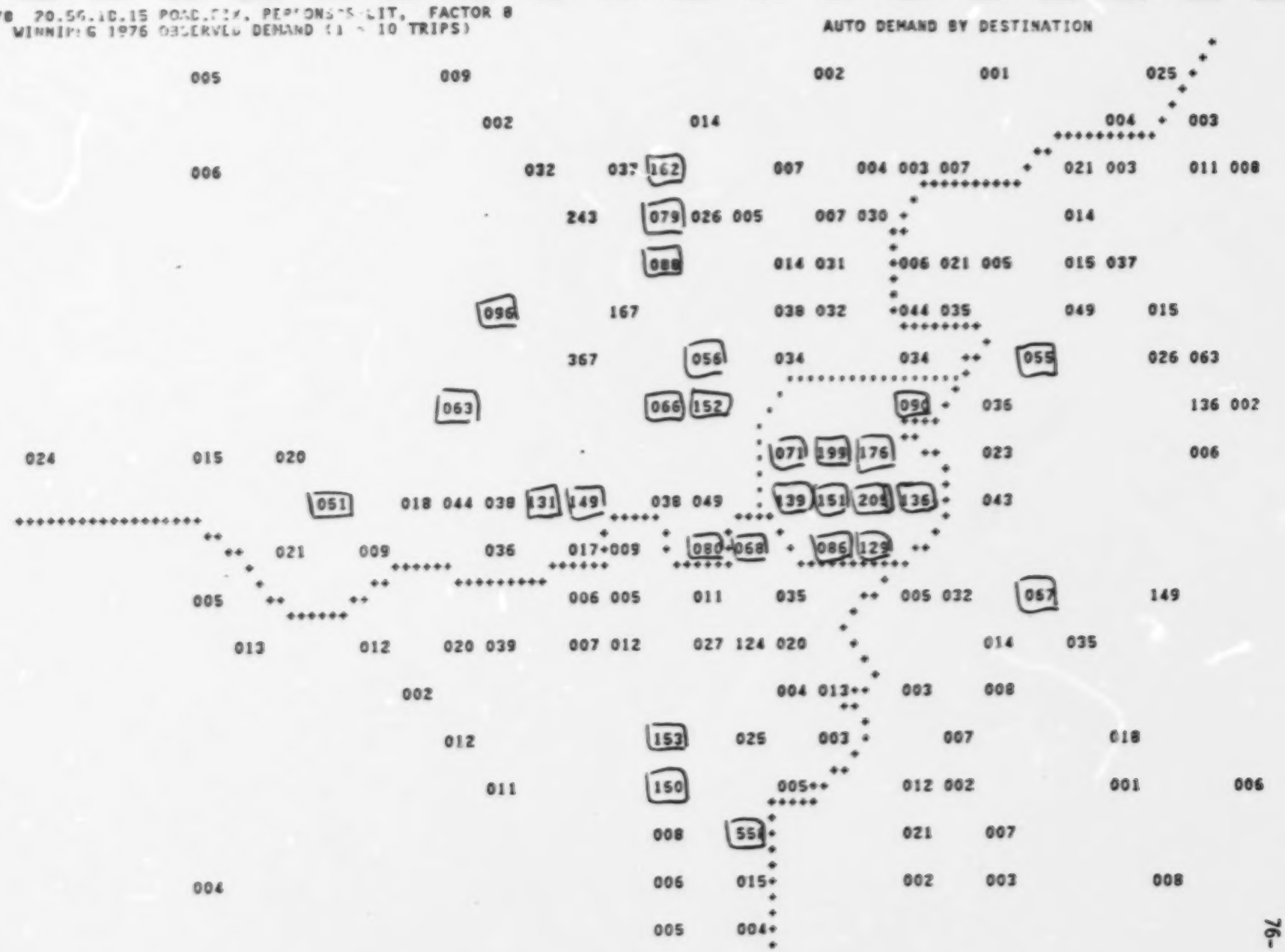

Figure 7.5 ☐ Destination demand larger than 500 trips

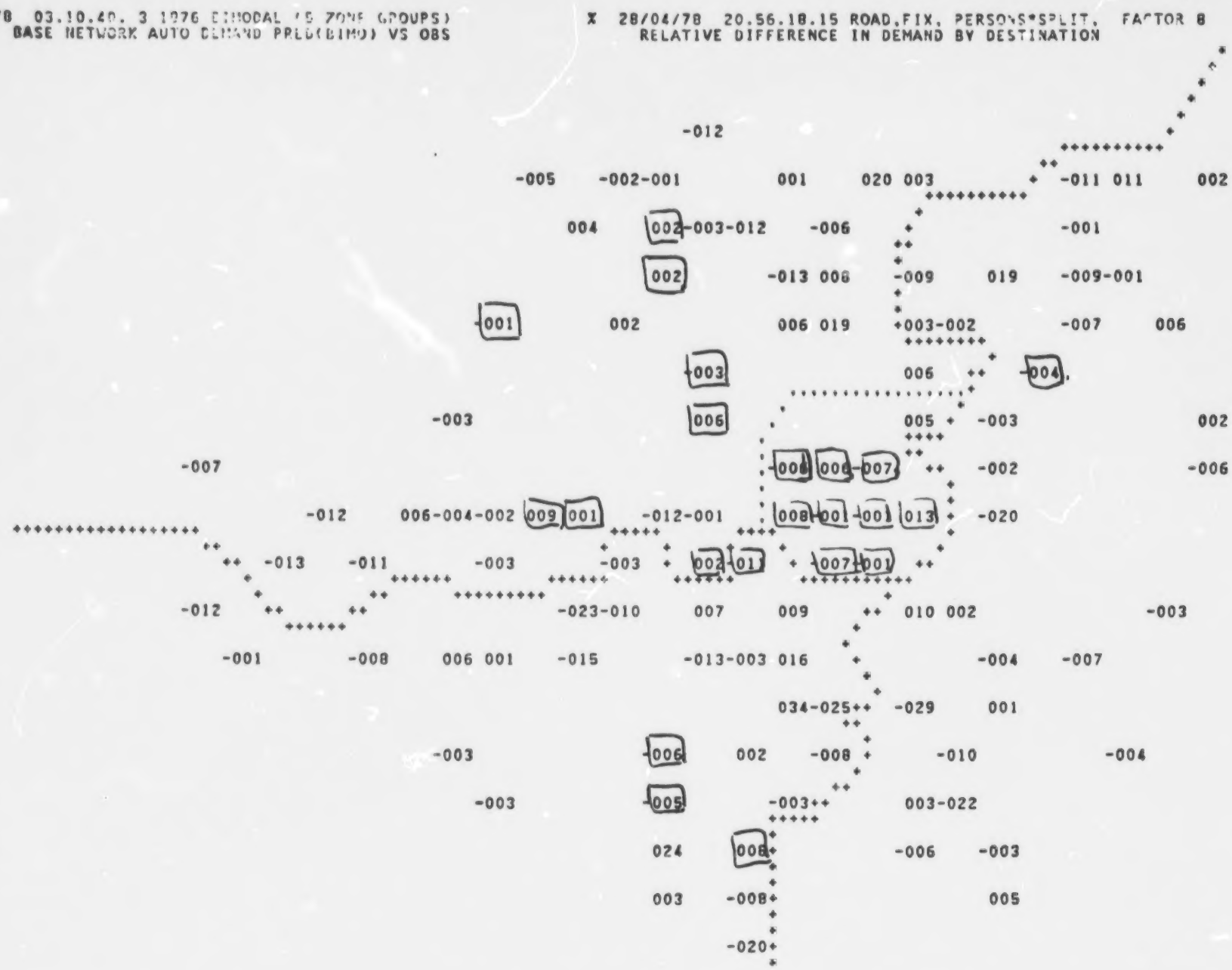

Figure 7.6 ☐ Relative difference in demand for origins larger than 500 trips

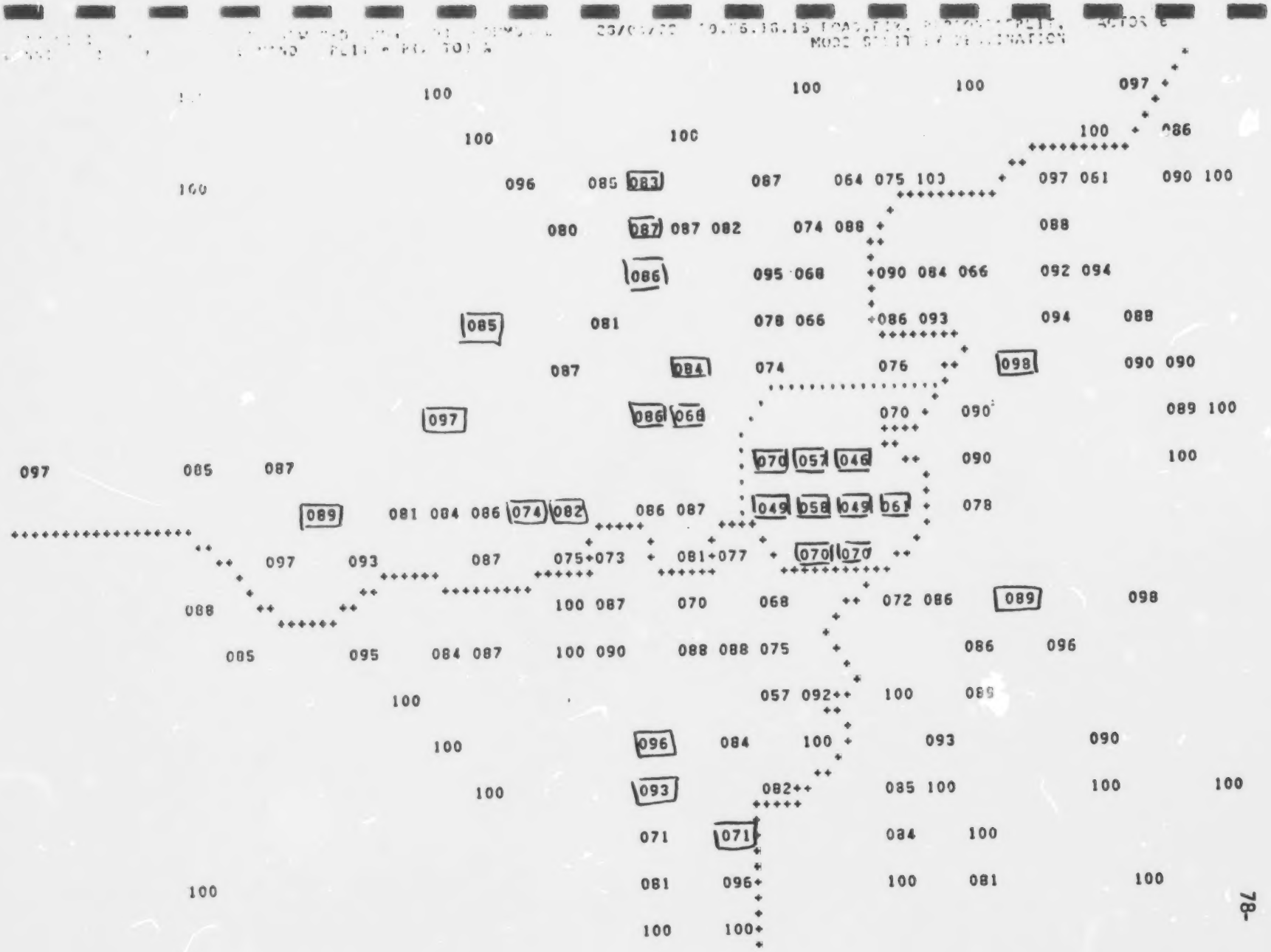

Figure 7.7 ☐ Destination demand larger than 500 trips

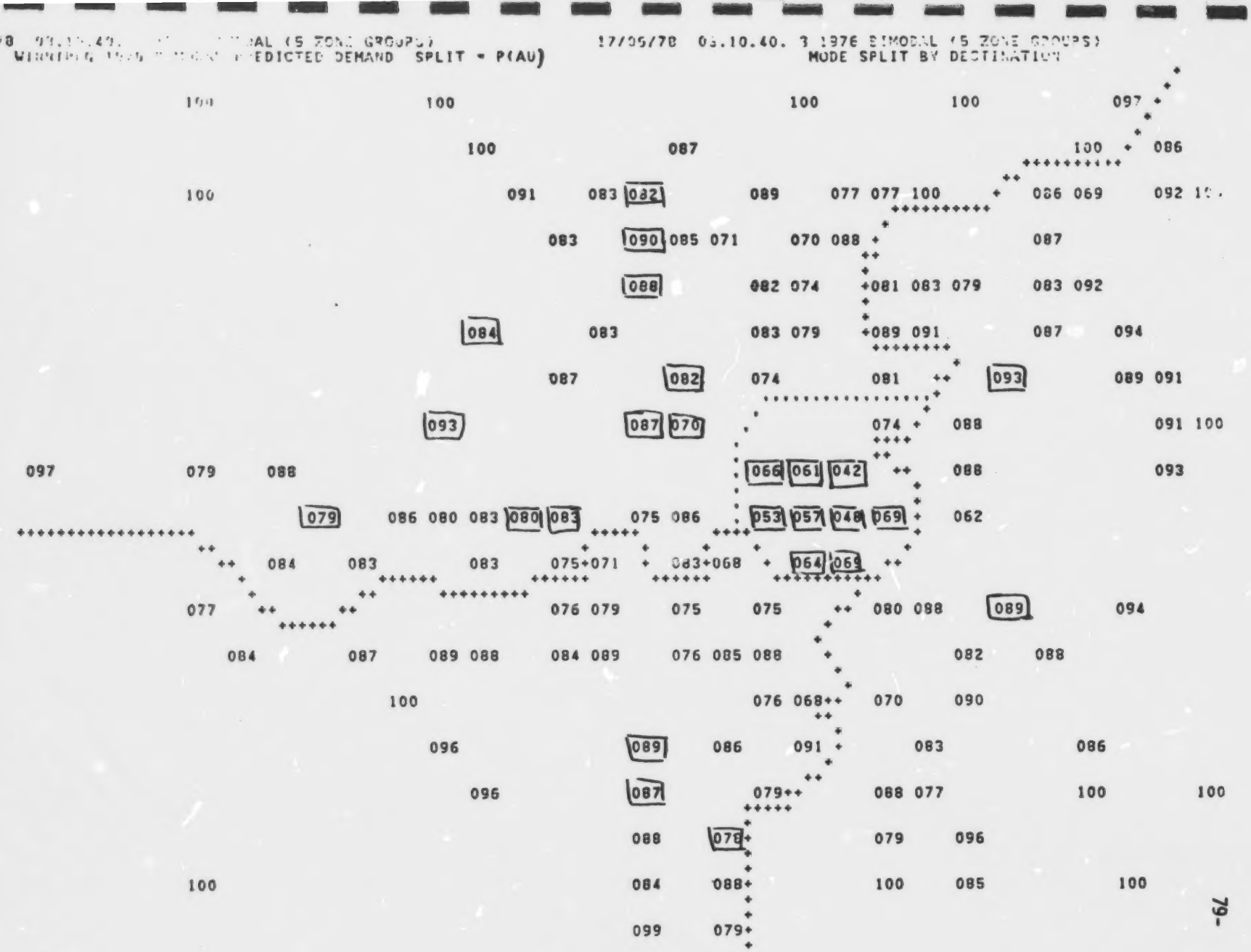

Figure 7.8 ▭ Destination demand larger than 500 trips

8. IMPACT OF THE BUSWAY AND ST. VITAL BRIDGE SCENARIOS

Introduction

There are several ways in which EMME may be used to simulate (predict) the impact of contemplated improvement scenarios. One may use the single mode assignment modules and thus simulate the impact of the scenario without changing the modal shares of the demand. This may be appropriate for some situations where only marginal improvements are made and the only interest is to anticipate the changes in route choice that result due to the modifications. However most of the current transportation planning methods in use have this capability. The other way to use EMME is to simulate the impact of each scenario with a full bi-modal run, which would predict the anticipated changes in modal share of demand as well. This capability is so far unique to EMME and in the description that follows we will discuss mainly the impacts of the contemplated scenarios predicted by full bi-modal runs of EMME.

The South-West corridor Busway

The impact of this scenario, as simulated by EMME, is of significant proportion. Figures 8.1 and 8.2 show the mean trip time in minutes by origin and the predicted difference in the mean time as a result of the busway. As can be easily seen by reference to Figure 8.2, nearly all the origin zones benefit from the busway, since most origin generate trips toward the University of Manitoba and the origin zones in the south-west quadrant of the city benefit as well from the busway. Figures 8.3 and 8.4 show the mean trip time in minutes by destination and the predicted

difference in the mean time as a result of the busway. It is easy to see that the impacts of transit travel time by destination are concentrated in the CBD arcs and the south-west corridor.

The transit ridership and the lines that use the busway is increased from 3,544 to 6,062. The difference of 2,518 passengers consists of 717 passengers attracted by auto to transit and 1,801 passengers that change their route choice to use bus lines that run on the busway. Table 8.1 indicates the maximal ridership and total number of passengers using the lines 41, 40 and 13 in the base year simulation and Table 8.2 indicates the same statistics for the simulation of the busway scenario.

Line No.	Maximal ridership		Total No. of pass. using the line
	Northbound	Southbound	
41	411	201	705
13	115	49	286
40	695	1,411	2,553
			3,544 Total

Table 8.1

(variable demand)

Line No.	Maximal ridership		Total No. of pass. using the line
	Northbound	Southbound	
441	725	715	1,880
413	283	111	632
440	1,179	1,570	3,345
40	73	112	205
			6,062 Total

Table 8.2

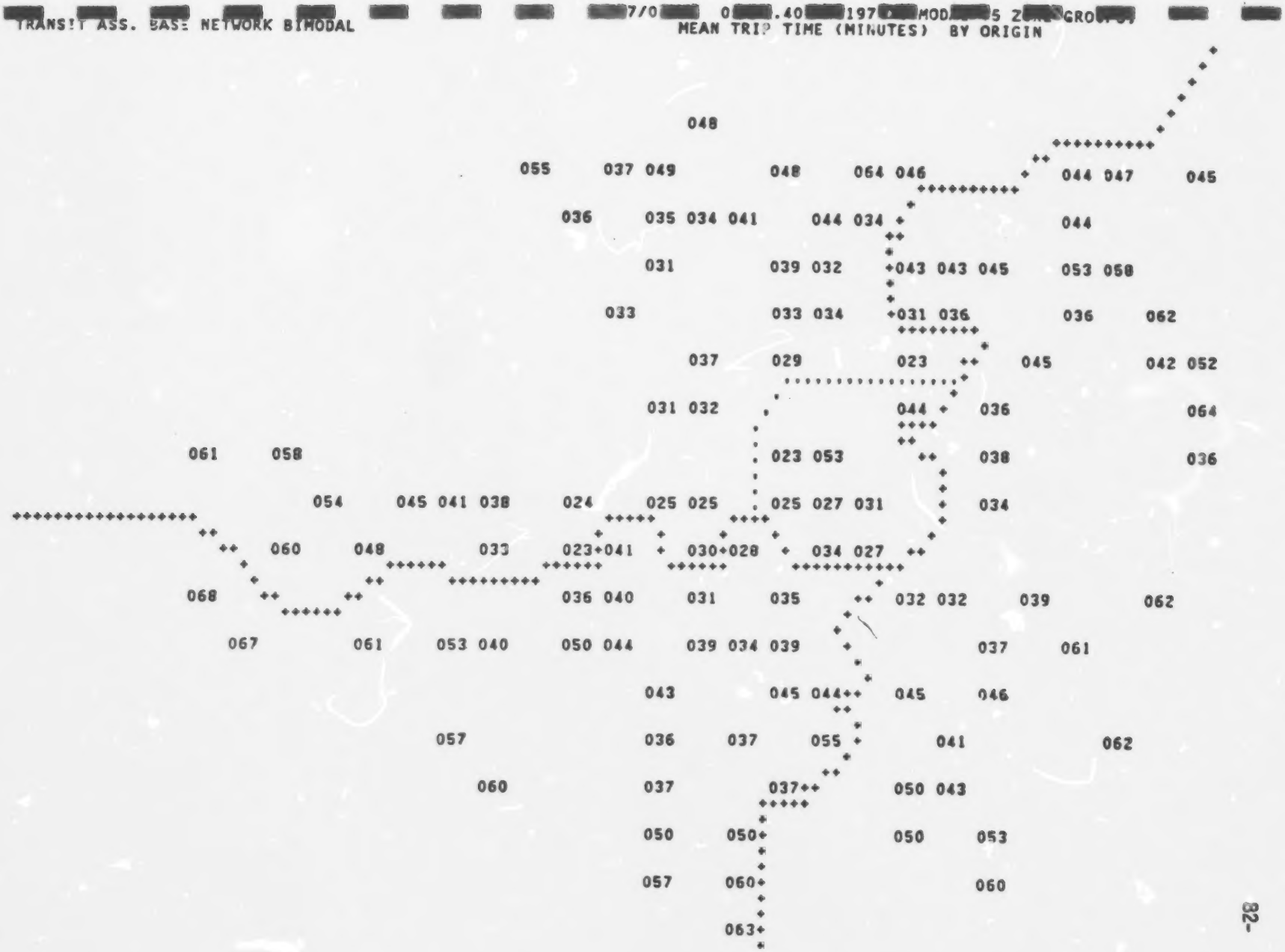
TRANSIT ASS. BASE NETWORK BIMODAL
MEAN TRIP TIME (MINUTES) BY ORIGIN

Figure 8.1

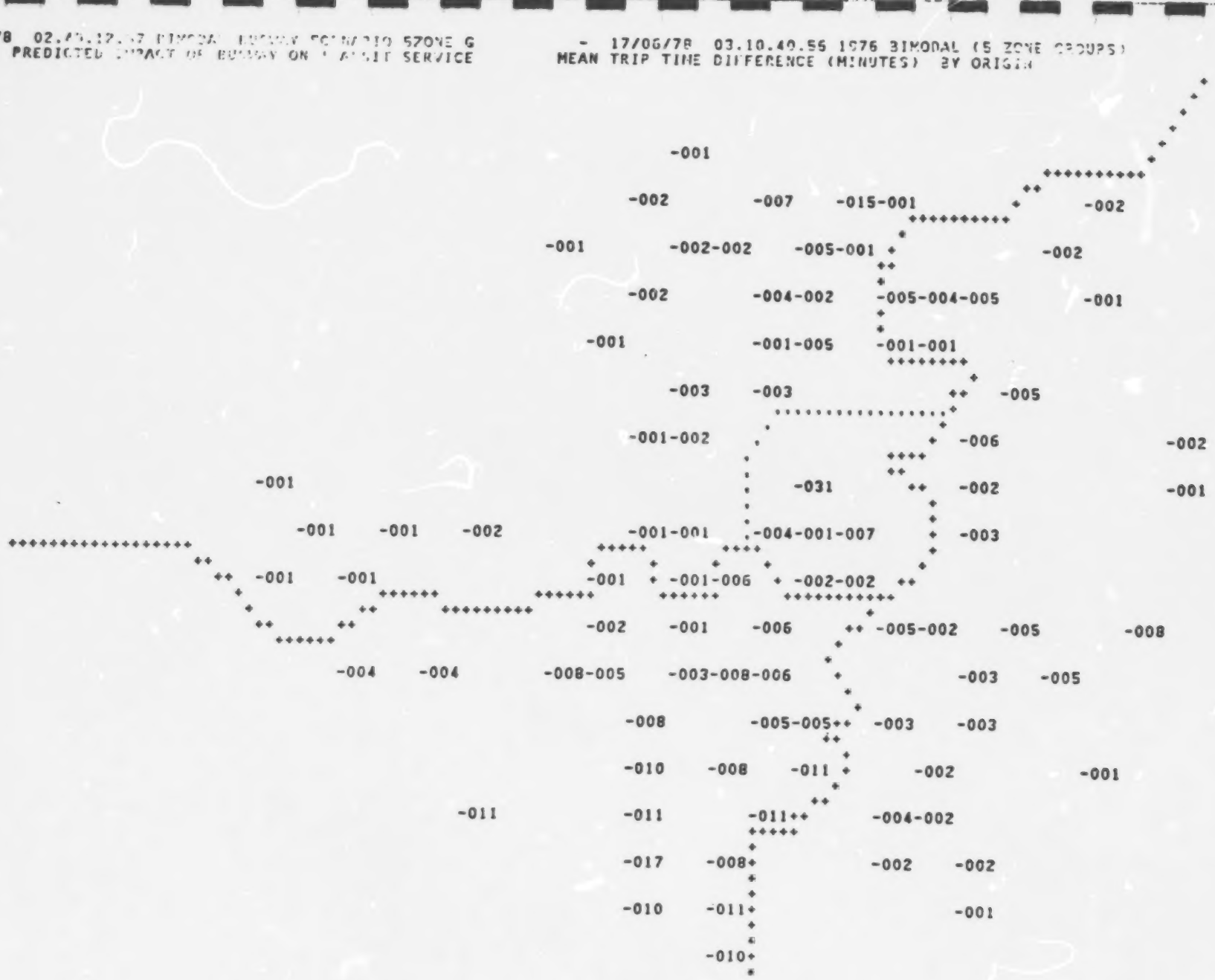
17/06/78 02.45.12.57 BIMODAL BUSWAY SCENARIO 5ZONE G
PREDICTED IMPACT OF BUSWAY ON TRANSIT SERVICE
- 17/06/78 03.10.40.55 1976 BIMODAL (5 ZONE GROUPS)
MEAN TRIP TIME DIFFERENCE (MINUTES) BY ORIGIN

Figure 8.2

TRANSIT ASS. BASE NETWORK BIMODAL

17/06/78 03.10.40.56 1976 BIMODAL (5 ZONE GROUPS)
MEAN TRIP TIME (MINUTES) BY DESTINATION

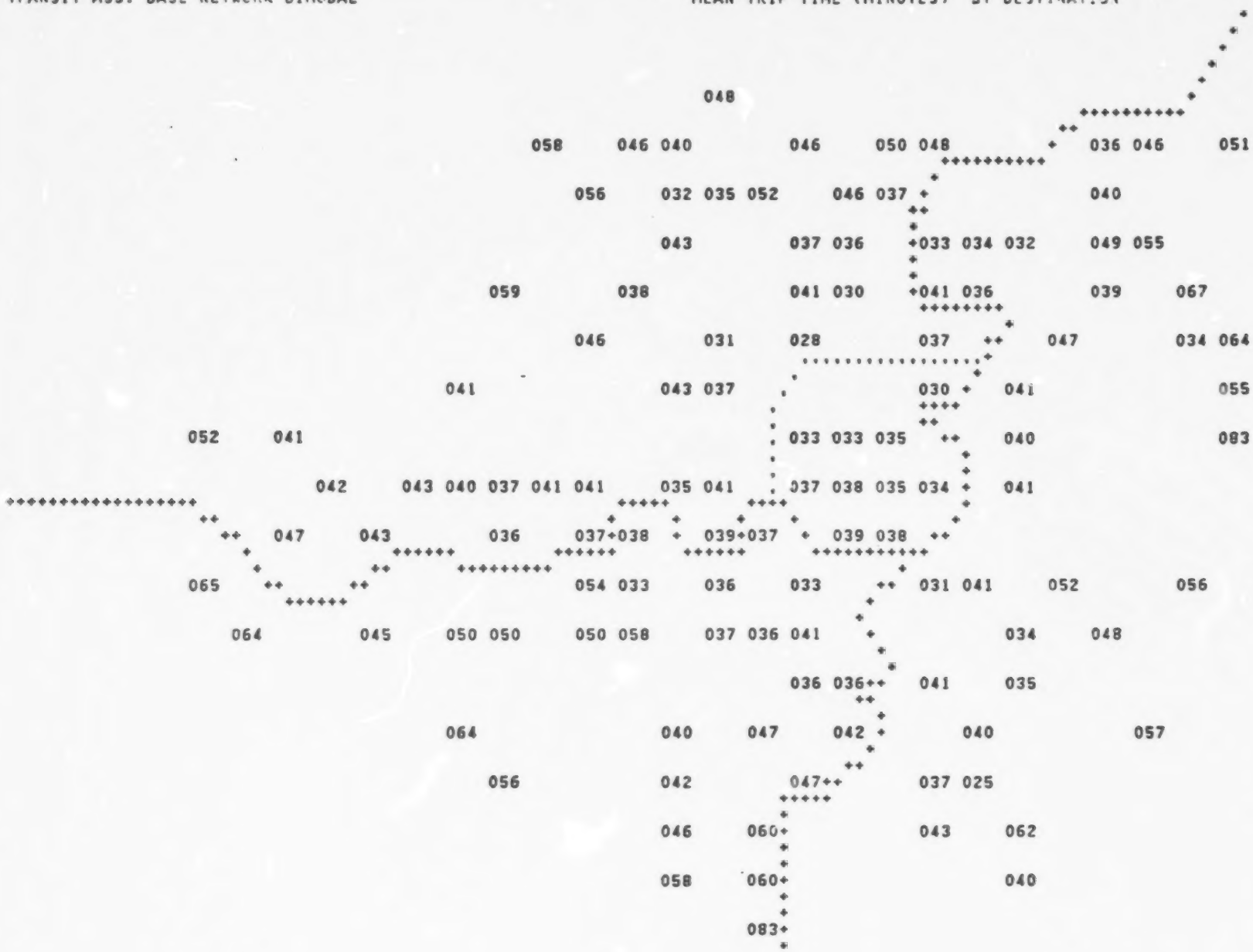

Figure 8.3

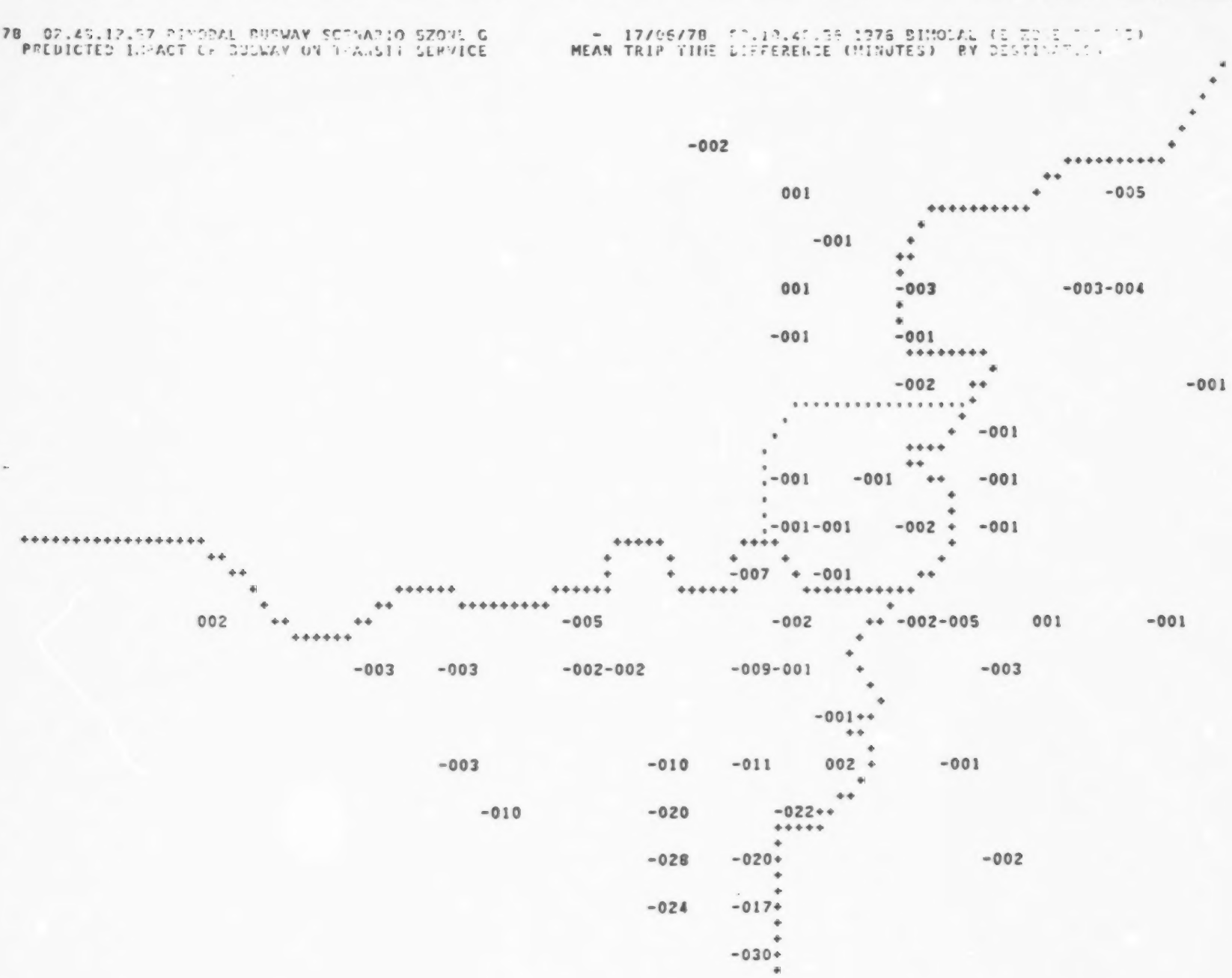
17/06/78 07.45.12.57 BIMODAL BUSWAY SCENARIO SZONE G
PREDICTED IMPACT OF BUSWAY ON TRANSIT SERVICE
- 17/06/78 1976 BIMODAL
MEAN TRIP TIME DIFFERENCE (MINUTES) BY DESTINATION

Figure 8.4

The global statistics are given in Table 8.3 below

	Base year	Busway Scenario
Passenger minutes	573 809.1	520 976.7
Average transit trip in min.	41.53	37.86
Average in-vehicle time	28.47	24.96
Average waiting time	4.45	4.49
Average access & egress time	8.62	8.41
Average number of transfers	.68	.75
Total number of transit-passengers	20 187.00	20 904.00
Global modal split	76.13 (auto)	72.53 (auto)

Table 8.3

The increase in transit demand by origin and destination may be seen in Figures 8.5 - 8.8. Figure 8.5 shows the transit demand by origin and Figure 8.6 shows the difference in demand by origin, with all differences larger than 10% enclosed in a rectangle. Similarly, Figures 8.7 and 8.8 show the transit demand by destination and the predicted differences in demand by destination.

Finally, we show in Figure 8.9 the profile of transit ridership in the northbound and southbound directions on the busway for the transit lines that use it. The maximum predicted ridership points are 2189 and 2374 respectively.

The computer time required for this simulation and the corresponding cost on the CDC Cyber 174 of the Université de Montréal are given below.

17/06/78 03.10.40. 1 1976 BIMODAL (5 ZONE GROUPS)
WINNIPEG 1976 BIMODAL PREDICTED DEMAND (1 = 10 TRIPS

TRANSIT DEMAND BY ORIGIN

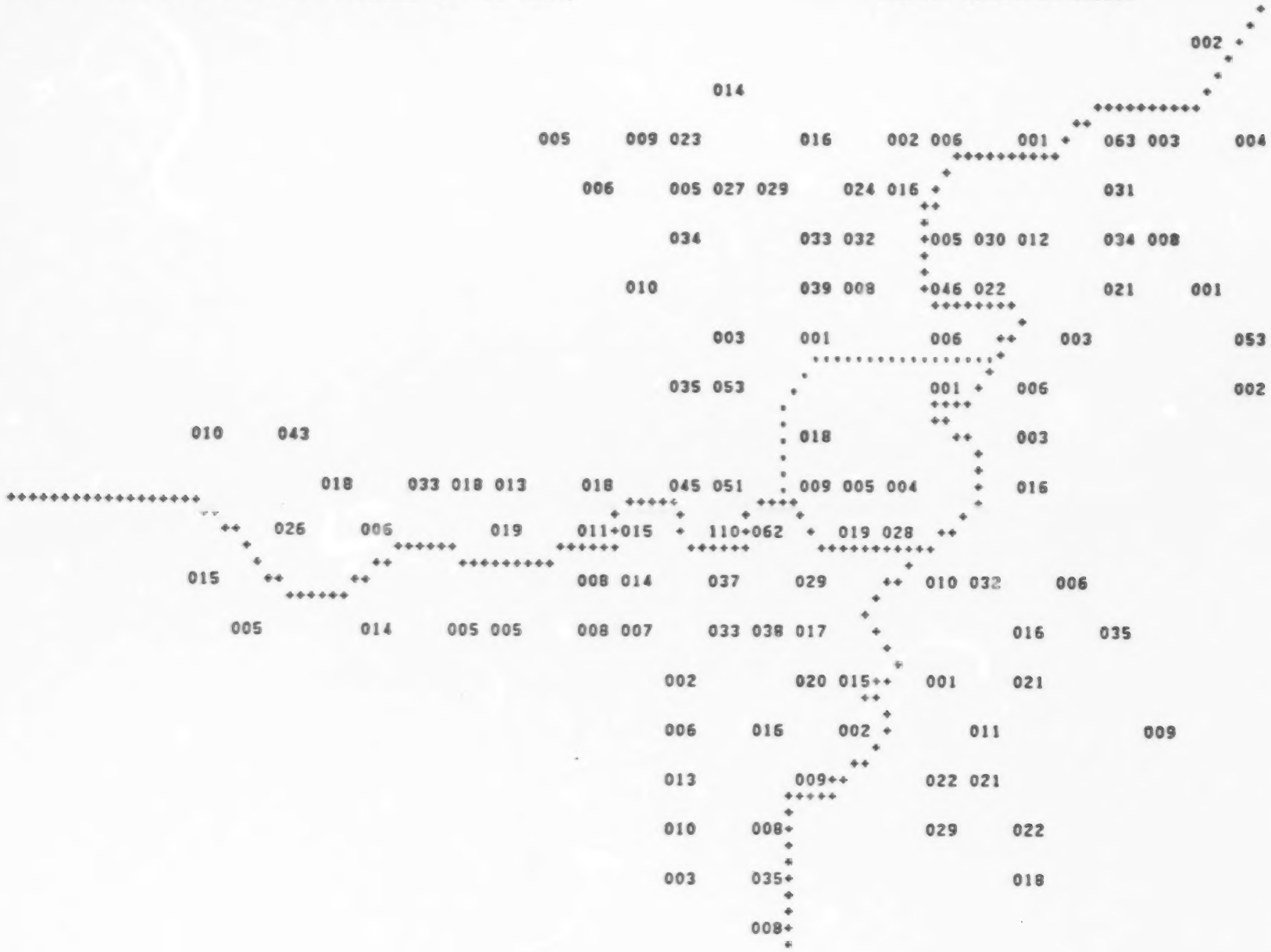

Figure 8.5

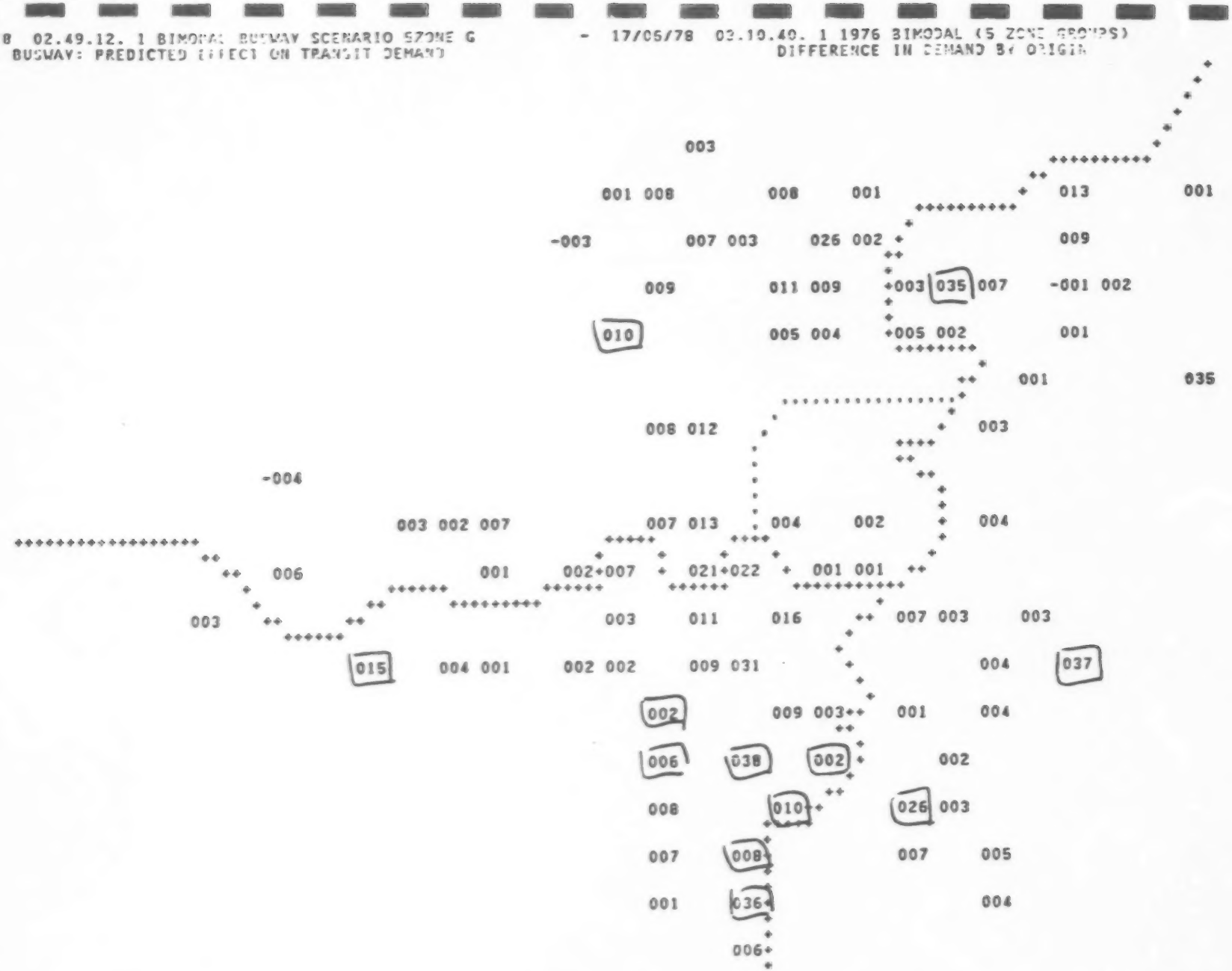

Figure 8.6 - ☐ more than 10% of observed demand - base year.

17/06/78 03.10.40. 1 1976 BIMODAL (5 ZONE GROUPS)
WINNIPEG 1976 BIMODAL PREDICTED DEMAND (1 = 10 TRIPS

TRANSIT DEMAND BY DESTINATION

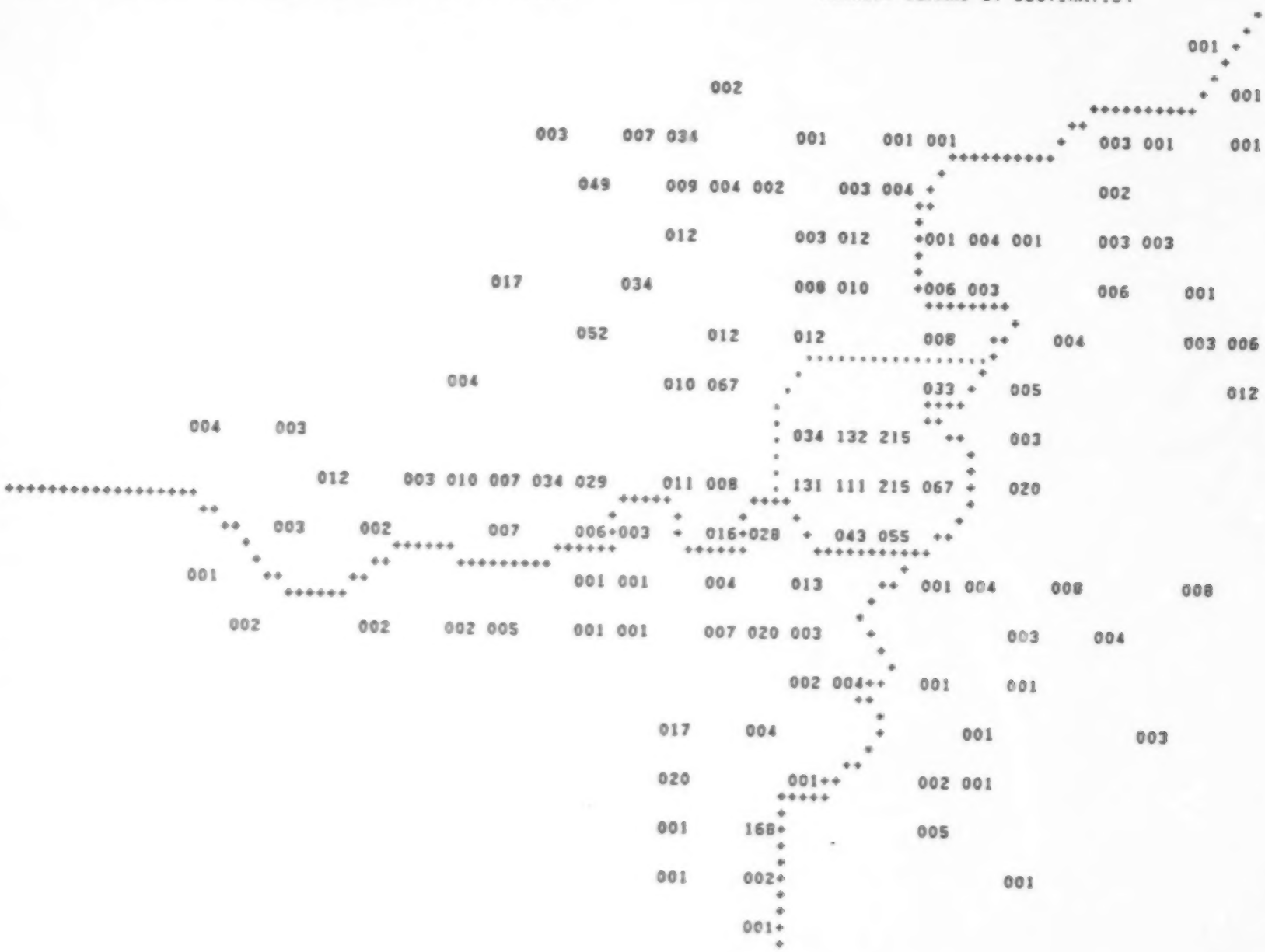

Figure 8.7

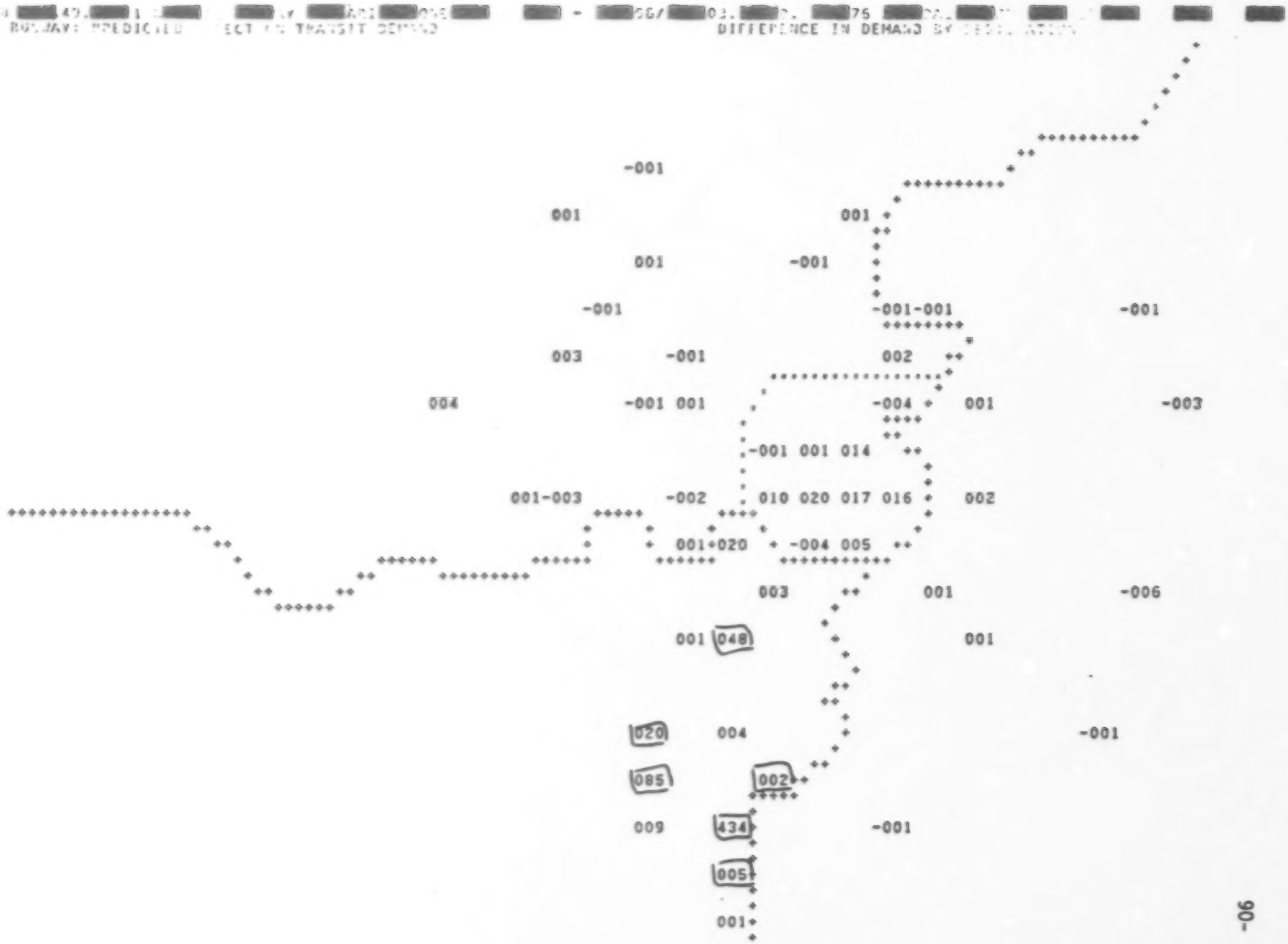

Figure 8.8 - ☐ Relative difference of more than 10%

Generate transit network	4.14
Calculate bus frequency	1.22
Calculate transit impedance	1206.79
Initialize road traffic demand	3.73
Perform road traffic assignment	2580.66
Modify transit link times	67.66
Calculate fixed transit demand	1.80
Calculate demand function (transit)	0.00
Perform transit assignment	465.52
Modify transit capacity	0.00

Central processor	$198.80
Input - output	24.00
Fast memory	584.80
Total	$807.70

Line No. \ Node No.	2134	2133	413	2012	4000	2013	4001	3813	2017	4002	2018	4003	355	2053	869	868
440		54	54	54	67	133	133	268	388	502	653	972	1098	1179	1146	934
441							427	473	500	543	605	654	698	725	692	577
413										99	160	207	254	285	274	109
TOTAL		54	54	54	67	133	560	741	888	1144	1518	1833	2050	2189	2112	1710

NORTHBOUND

Line No. \ Node No.	868	869	2053	355	4003	2018	4002	2017	393	4001	2013	4000	2012	413	2133	2134
440		1120	1156	1256	1496	1455	1570	1513	1566	1503	1332	1332	1327	1317	1317	1317
441		496	512	556	678	660	713	692	715	619	617					
413		75	79	89	41	70	91	48								
TOTAL		1691	1747	1901	2215	2185	2374	2253	2281	2192	1949	1332	1327	1317	1317	1317

SOUTHBOUND

Figure 8.9 Load on transit lines in the busway

The Fort-Garry - St.Vital Bridge

The impact of this scenario, as simulated by EMME, is localized to the Fort Garry and St.Vital community areas. Figures 8.10 and 8.11 show the mean trip time by auto by origin and the corresponding mean trip time difference by origin. It is clear that most of the origin zones that benefit are those to the east of the bridge. Similarly, Figures 8.12 and 8.13 show the mean trip time difference by destination and the corresponding mean trip time difference by destination. Again, it is easy to see that most of the destination that benefit from the bridge are to the west of it.

The global statistics merely confirm the localized spatial impacts of this scenario. They are given in Table 8.4 below:

	Base network	Fort Garry - St.Vital bridge
Vehicle hours	20,438.63	19,914.34
Vehicle miles	379,679.73	375,938.20
Average speed mph	18.58	18.88
Global modal split	76.13 (auto)	76.63 (auto)

Table 8.4

There are 185 trips that are predicted to change from transit to auto, which represent .5% change in the modal split. There is a 2.52% reduction in the total vehicle hours and a 1% reduction in total vehicle miles.

The most significant impact is the reduction of the hourly volume on the perimeter bridge, link (325-423) from 1109 to 68. These trips will be using the new bridge, which has a predicted hourly volume of 1987.

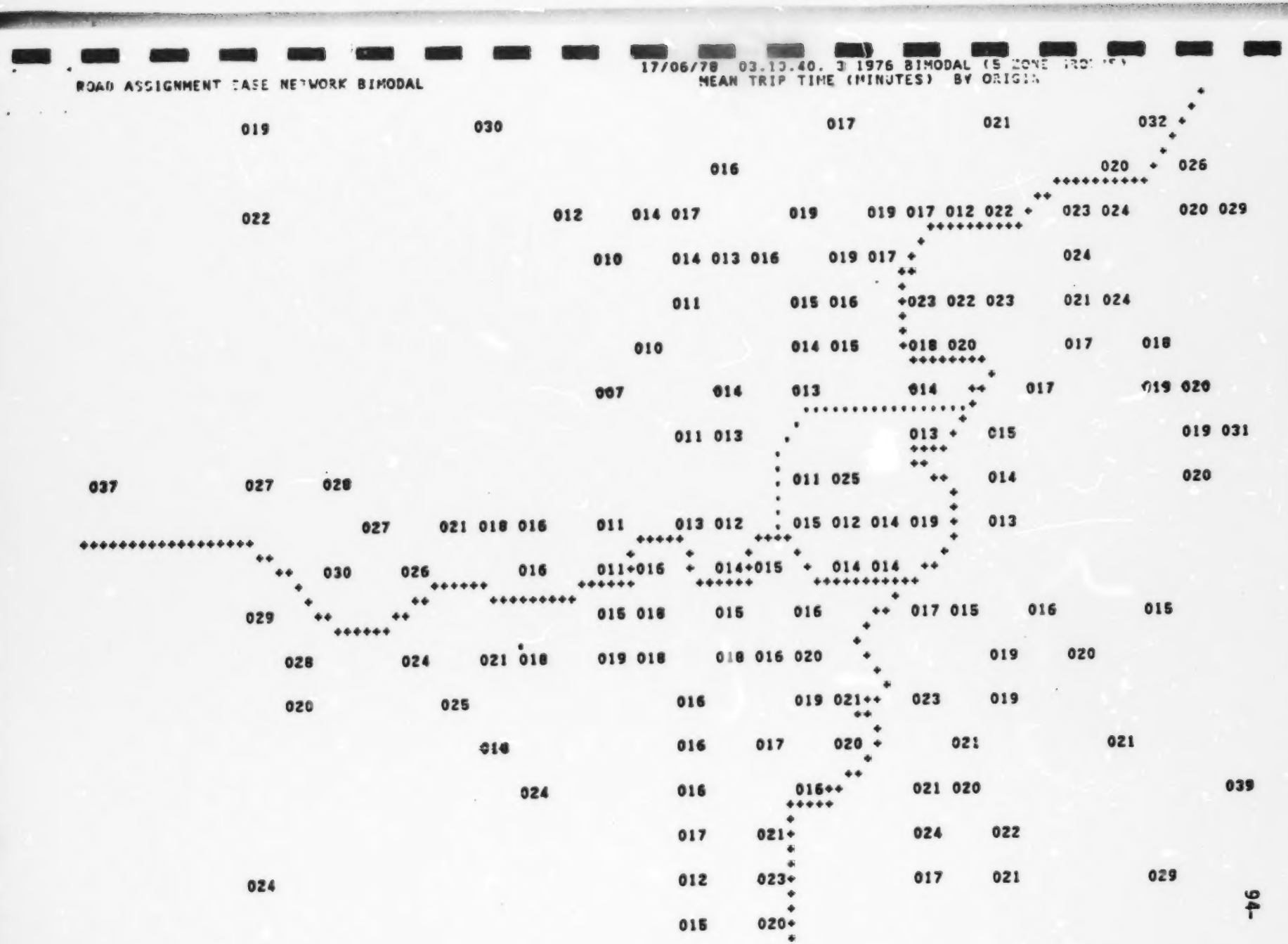
ROAD ASSIGNMENT BASE NETWORK BIMODAL
17/06/78 03.10.40. 3 1976 BIMODAL (5 ZONE GROUPS)
MEAN TRIP TIME (MINUTES) BY ORIGIN

Figure 8.10

17/06/78 01.[illegible] 5 B[illegible] (T-VITAL SCENARIO 5 ZONE G
PREDICTED IM[illegible] ST-VITAL BRIDGE ON CAR TIMES

- 17/06/78 03.10.40. 3 1976 BIMODAL (5 ZONE GROUPS)
MEAN TRIP TIME DIFFERENCE (MINUTES) BY ORIGIN

Figure 8.11

ROAD ASSIGNMENT BASE NETWORK BIMODAL

17/06/78 03.10.40. 3 1976 BIMODAL (5 ZONE GROUPS)
MEAN TRIP TIME (MINUTES) BY DESTINATION

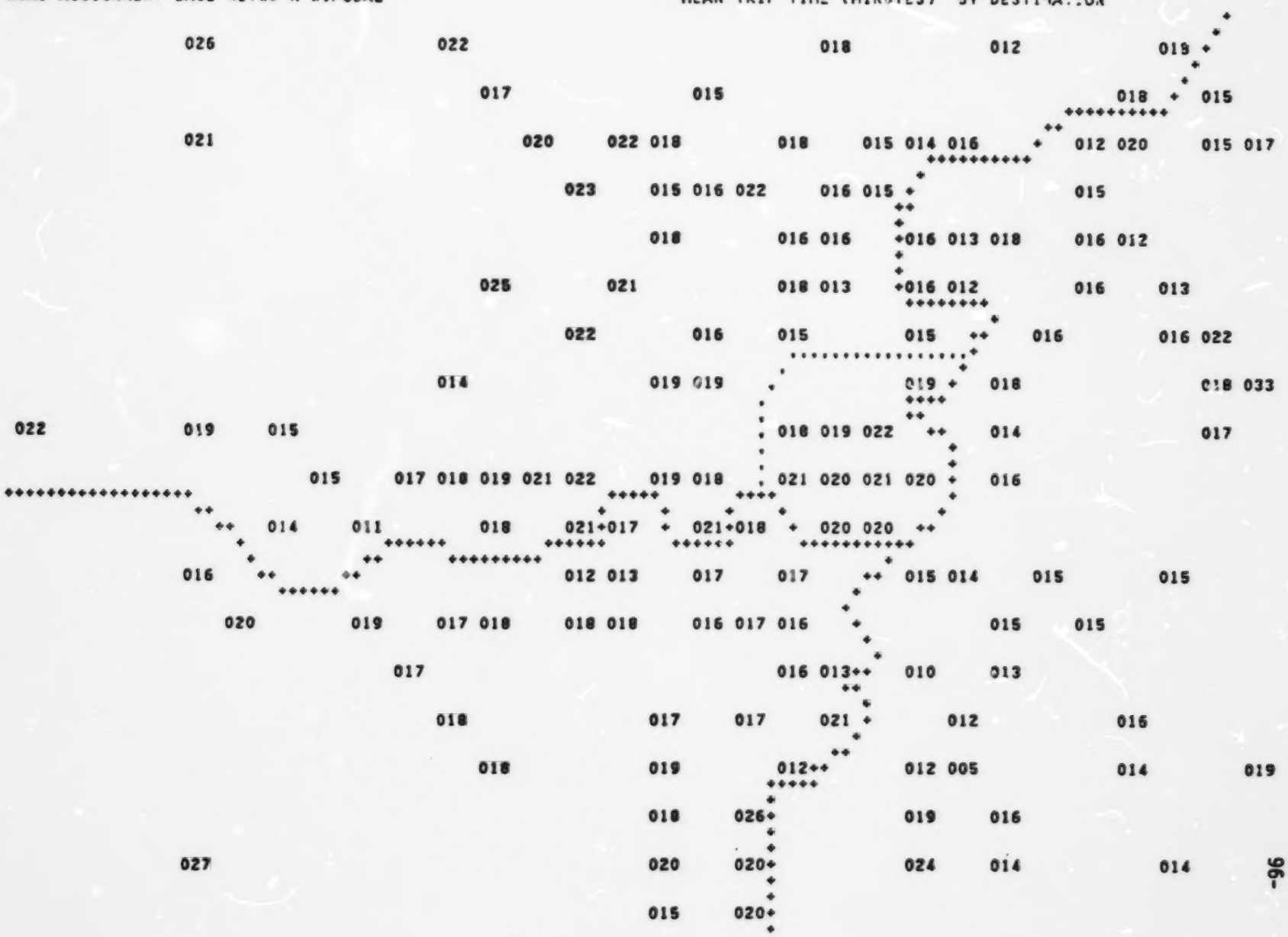

Figure 8.12

17/06/78 01.02.23. 5 BIMODAL ST-VITAL SCENARIO 5 ZONE G
. . PREDICTED IMPACT OF ST-VITAL BRIDGE ON CAR TIMES

- 17/06/78 03.10.40. 3 1976 BIMODAL (5 ZONE GROUPS)
MEAN TRIP TIME DIFFERENCE (MINUTES) BY DESTINATION

Figure 8.13

The volume on the bridges in the south-east wuadrant of the city are given in Table 8.5 below.

Bridges	Link	Hourly volume Before	After
Provencher	264- 871	2,017	2,002
Norwood	270- 356	3,022	2,842
St.Vital	306- 380	1,822	1,553
Fort Garry - St.Vital	1011-1060	-----	1,987
Perimeter	325- 423	1,109	68

Table 8.5

The computating times and costs for this scenario are as follows

Generate transit network	3.82
Calculate bus frequency	1.24
Calculate transit impedance	1109.58
Initialize road traffic demand	3.50
Perform road traffic assignment	2701.77
Modify transit link times	70.55
Calculate fixed transit demand	1.77
Calculate demand function (transit)	0.00
Perform transit assignment	425.33
Modify transit capacity	0.00

Central processor	$198.00
Input - Output	24.00
Fast memory	586.00
Total	$808.00

9. COMPUTER GRAPHICS NETWORK AND TRAFFIC FLOW ANALYSIS

A set of independent programs, compatible with EMME network structures, data bank and files containing assignment results, were developed to produce computer plots of the automobile and transit networks together with predicted link flows. These plots are designed to aid in debugging network data and to allow rapid assimilation of the model results by producing a global picture of the predicted link volumes. They also serve to maintain up-to-date maps of the networks.

The network descriptions and node coordinate information are extracted from the data bank. The node coordinates were obtained by geo-coding maps of the network covering the study area. Since the scale and orientation of the regional map differed from that for the downtown area, coordinate transformations to ensure compatibility were made before entering the information into the data bank. Predicted vehicle and transit link volumes are accessed from intermediate files generated by EMME. Additional information describing the area to be plotted and the desired scale is user supplied.

The plot area is contained within a rectangle inclined at an angle Θ to the x-axis of the data bank coordinate system (Fig. 9.1). It is completely defined by the specification of four nodes, one on each side of the rectangle, and Θ. A rectangle internal to this region, defined in a similar manner, may be optionally omitted from the plot. This allows for the separate plotting of the regional and downtown portions of the networks which is desirable since the latter usually requires a larger scale.

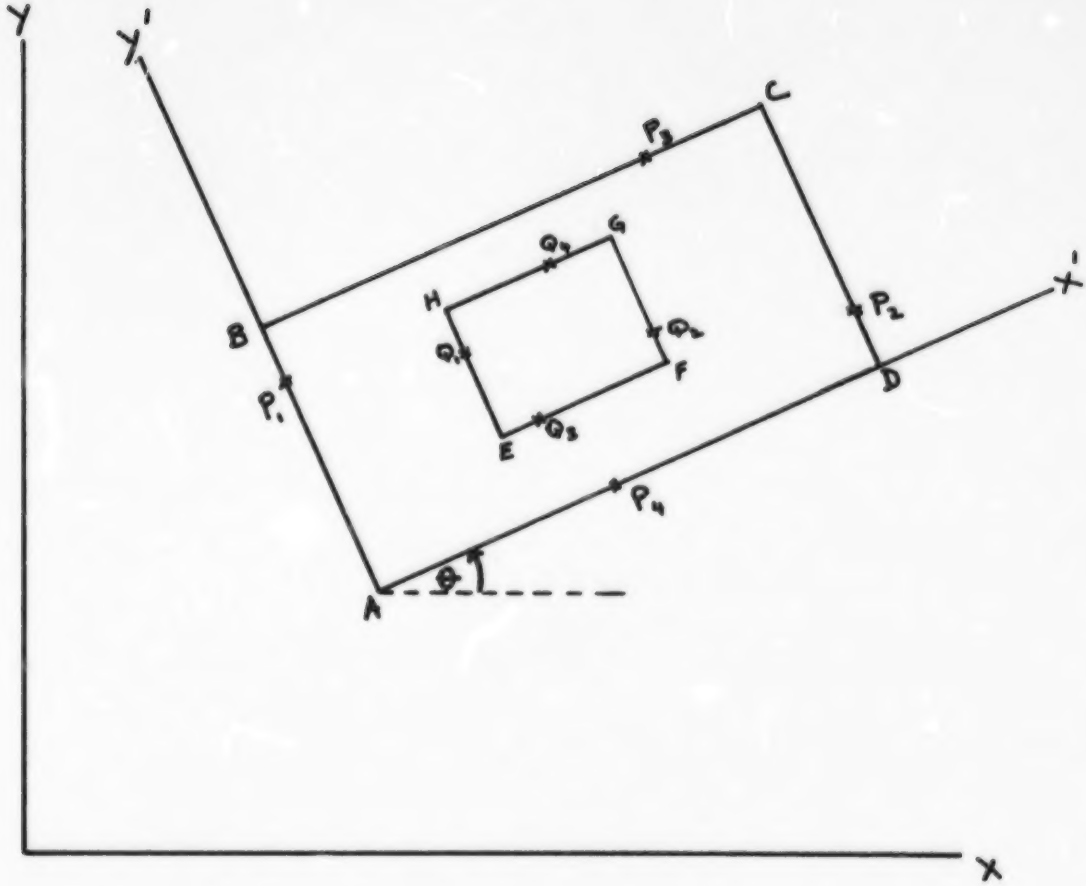

Fig. 9.1 The points P_i, i=1, ..., 4, define the rectangle ABCD to be plotted.

Q_i, i=1, ..., 4, define rectangle EFGH to be omitted.

θ is the angle of rotation, counterclockwise sense of the plot x-axis with respect to the x-axis of the data bank coordinate system.

The plot size is determined by the nodes P_1, P_2, P_3, P_4 and the plot scale which is user specified. The plot height AB is limited by the width of the plot paper. 2½ inches at the top of the plot is reserved for printing a title, the scale (and volume scale in the case of volume plots), and a north direction arrow. Characteristics of each plot are outlined separately below.

1. Vehicle network

A pair of connected nodes is joined by a solid line with a directional arrow located at its midpoint if the corresponding link is one-way. Node numbers are drawn parallel to the x-axis. Centroid connectors are indicated as dashed lines (Fig. 9.2).

2. Transit network (Fig. 9.3).

This has the same characteristics as the vehicle network plot with the additional information of the bus line numbers serving each link included (if the links are long enough to contain them). Also nodes lying in express bus routes are doubly defined. Optionally, the routes for a subset of bus lines may be plotted.

3. Vehicle assignment (Fig. 9.4).

Connected nodes are joined by dashed lines to indicate the network structure. A link volume is represented by a solid rhomboidal segment, the width of the segment indicating the volume assigned to the link. The traffic volume is printed at the midpoint of the segment. On centroid connectors and "dummy" links, volume numbers only are plotted.

VEHICLE NETWORK

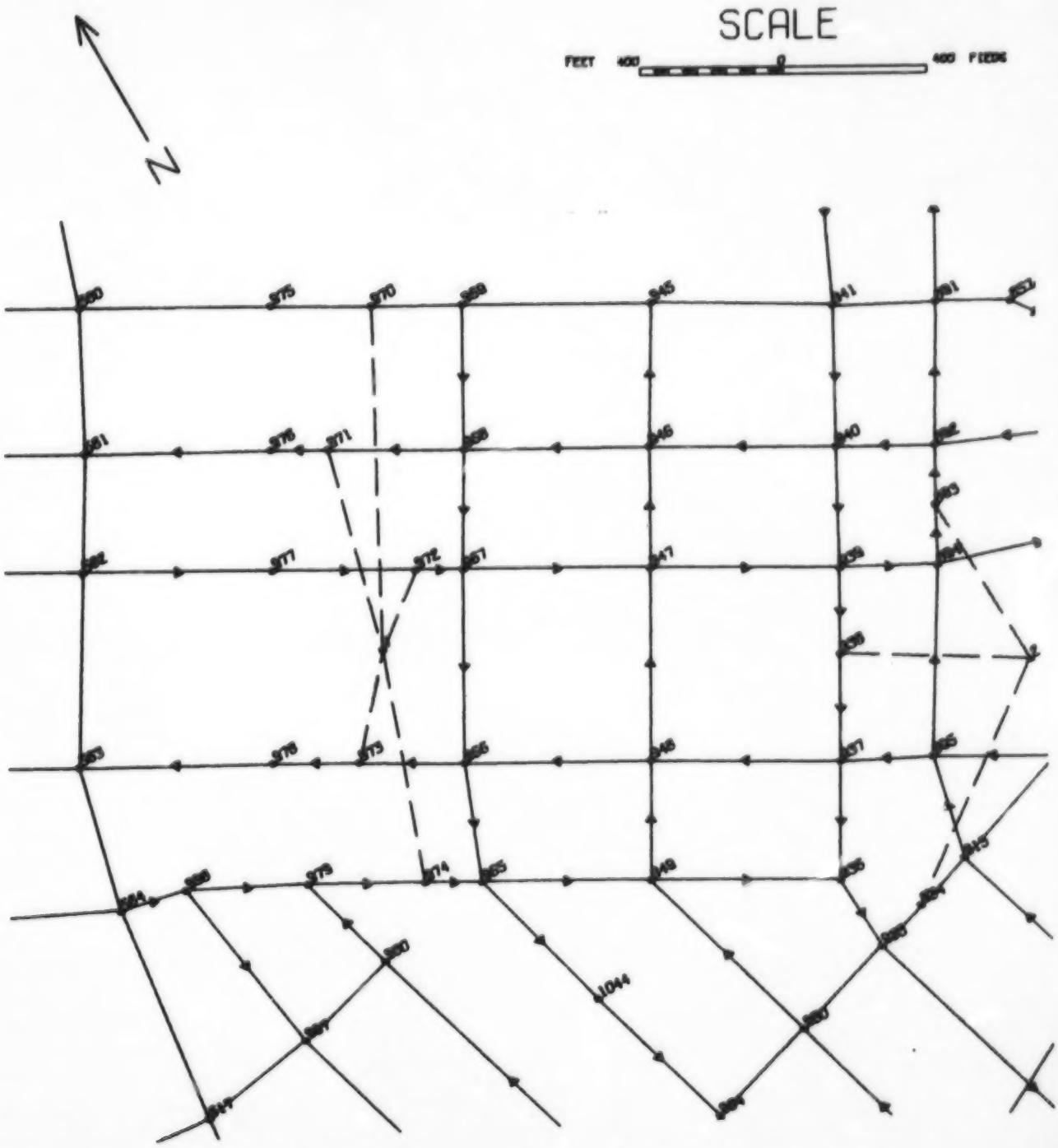

Figure 9.2

TRANSIT NETWORK

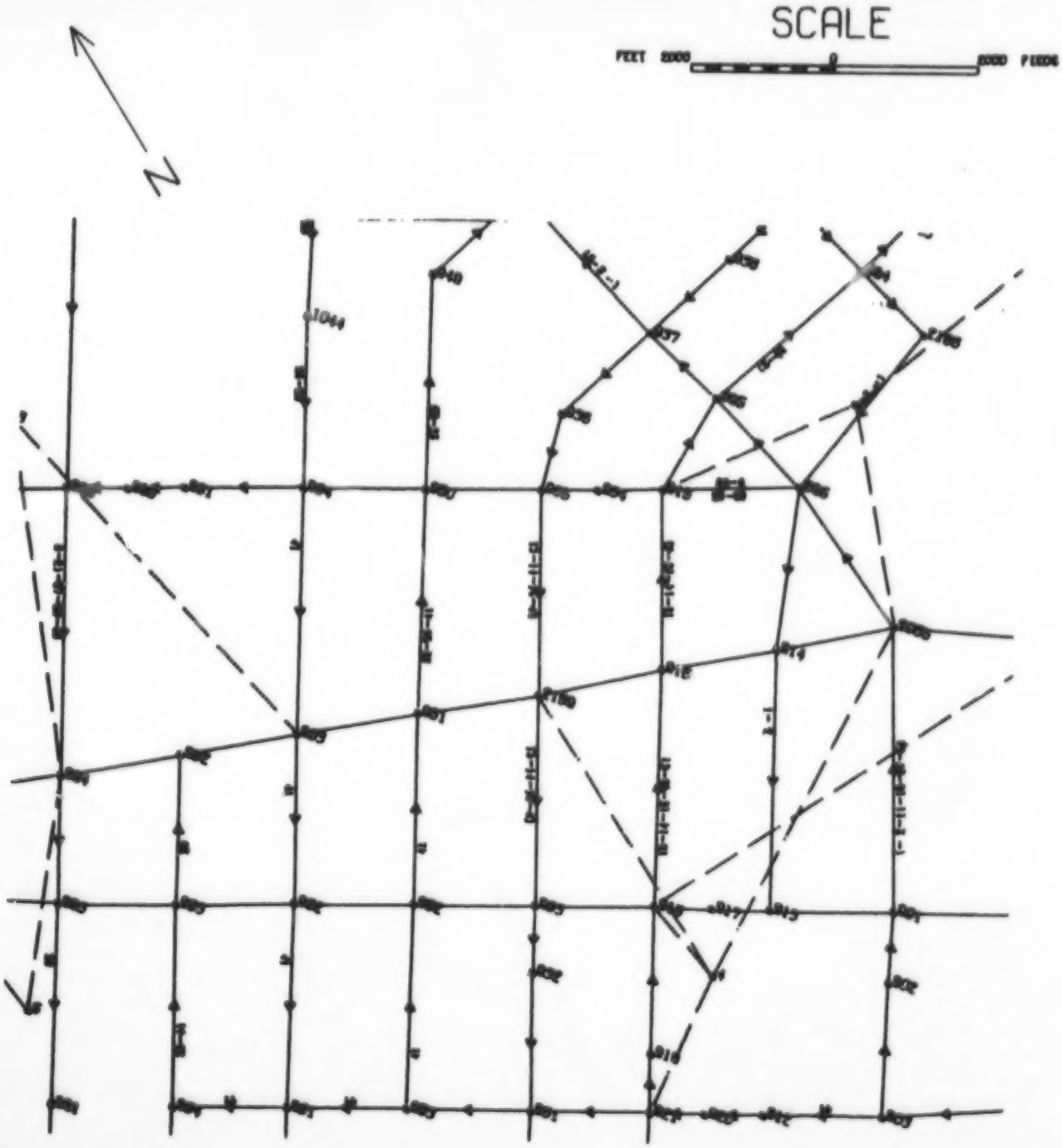

Figure 9.3

ROAD ASSIGNMENT

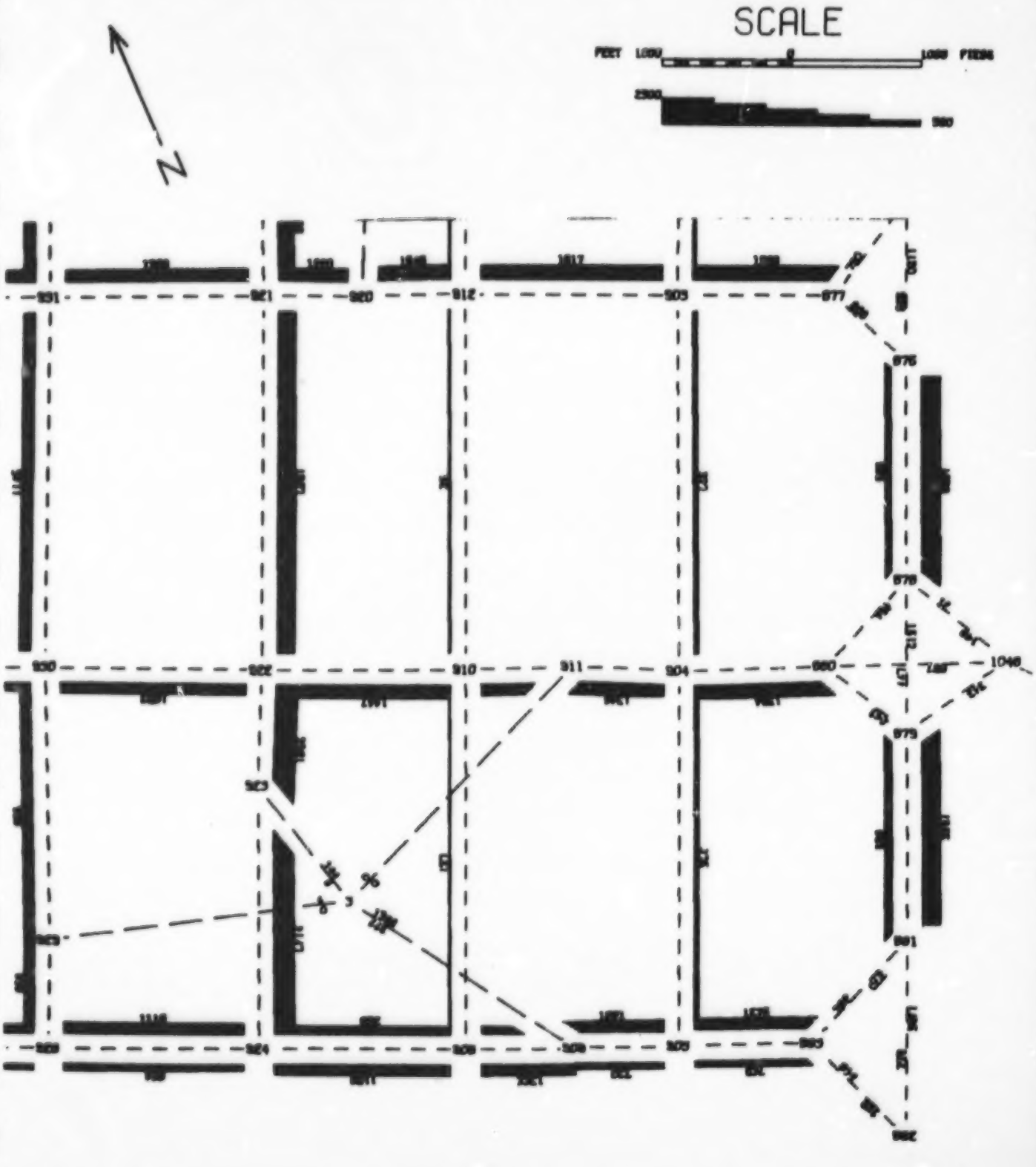

Figure 9.4

4. Transit assignment (Fig. 9.5).

This is similar to the vehicle assignment plot with the additional option of plotting the link volumes for a subset of bus lines. Link volumes contributed by express lines are included with those of other lines using the same physical link. On these links only the lower node numbers are used for link identification.

Plotting costs are small in comparison to the total computing cost incurred in performing an assignment. A volume plot for a dense network of approximately 1½ x 2½ miles in area, plotted at a scale of 400 ft./in., requires about 1 hour of plotting time (a cost of around $30. at 1978 commercial rates).

TRANSIT ASSIGNMENT

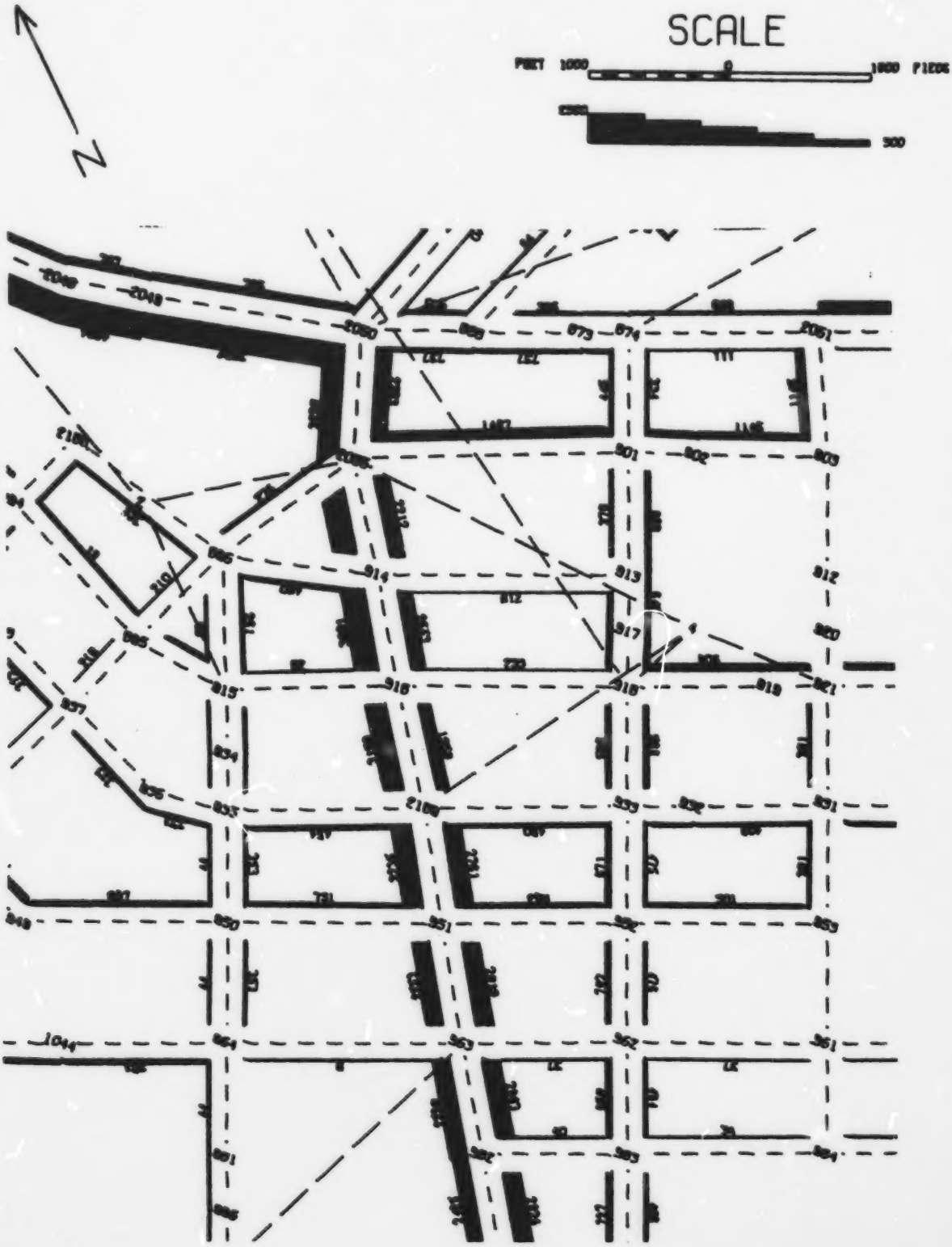

Figure 9.5

10. CONCLUSIONS

A summary report involves a 'summary' conclusion. During the two years that elapsed while project EMME was carried out many conclusions were drawn regarding the calibration and validation of large scale relatively detailed urban transportation planning models. The main ones are that the use of sophisticated models, such as EMME, is feasible and the simulation of scenarios results in refined and fully detailed evaluations, which would not be possible otherwise; the main obstacle that presents itself is the quality of the data available and the calibration of the demand model. Fortunately, in this demonstration study we worked with very good data and we succeeded in calibrating a satisfactory modal split model.

While the costs of building up the necessary data base and calibrating the model are relatively high, the use of the model is not expensive. The fiture of $800, cost for each bi-modal simulation is reasonable, when one considers that the analyst's time to set up a scenario and analyse the Emme output is of the order of half a day to a day.

We believe that EMME has been demonstrated to be useful in the analysis of the scenarios considered and has much potential as an urban transportation planning method which may be applied elsewhere in Canada.

APPENDIX 1

PARAMETERS OF THE 1976 VOLUME/DELAY CURVES

CACO	SPEED LIMIT MPH	TRC/WATS FREE flow speed/ min.per mile	BPR		FREE FLOW TIMES/MINUTES PER MILE			
			α	β	BPR1	BPR2	BPR3	BPR4
1	0-30	29.7/2.02	.7312	3.6596	26.7/2.25	12.0/5.00	17.5/3.43	15/4.00
2	0-30	24.8/2.42	.6128	3.5038	22.7/2.25	17.0/3.53	22.7/2.64	17/3.53
3	0-30	26.7/2.25	.8774	4.4613	23.1/3.00	20.0/3.00	23/2.61	20/3.00
4	0-30	26.7/2.25	.6846	5.1644	22.0/2.73	28.5/2.11	23/2.61	23/2.61
5	0-30	27.9/2.15	1.1465	4.4239	undetermined	23.8/2.52	25/2.40	25/2.40
6	31-40	30.0/2.00	.6190	3.6544	30.0/2.00	30.0/2.00	30.0/2.00	30.0/2.00
7	31-40	32.4/1.85	.6662	4.9432	29.3/2.05	29.3/2.05	32.4/1.85	32.4/1.85
8	31-40	32.4/1.85	.6222	5.1409	29.3/2.05	29.3/2.05	32.4/1.85	32.4/1.85
9	31-40	35.3/1.70	1.0300	5.5226	30.5/1.97	30.5/1.97	35.3/1.70	35.3/1.70
10	41-50	41.4/1.45	.6609	5.0906	37.3/1.61	37.3/1.61	41.4/1.45	41.4/1.45
14	41-50	41.4/1.45	.5423	5.7894	36.4/1.65	30.0/2.00	41.4/1.45	41.4/1.45
15	41-50	41.4/1.45	1.0091	6.5856	39.8/1.5.	39.8/1.51	41.4/1.45	41.4/1.45
16	+50	55.0/1.09	.8776	4.9287	58.6/1.02	58.6/1.02	55.0/1.09	55.0/1.09
17	+50	55.0/1.09	.7699	5.3443	56.1/1.02	56.1/1.07	55.0/1.09	55.0/1.09
18	+50	55.0/1.09	1.1491	6.8677	58.1/1.03	54.5/1.10	55.0/1.09	55.0/1.09

APPENDIX 2

DETAILS OF O/D SURVEY DATA

The details of the data formats of the O/D survey data are as follows:

Position	Subject	Description
1	Transaction	Blank
2-6	Questionnaire No.	Numeric, right justified Nos. 1-50,000 - Home interviews Nos. 50,001-59,999 - Apartment building mail survey Nos. 60,000 and higher - Student mail survey
7	Questionnaire Code	Numeric or blank; 1, 2 or 3 for City of Winnipeg use only
8	Trip Purpose	Numeric; 1 = work and 2 = college student
9-22	Civic No.	Alphanumeric or blank
12-46	Street Name	Alphanumeric
47-49	Origin Zone No.	Numeric
50-51	Property Code	Numeric or blank
52	Day of Survey	Numeric or blank; 1 = monday 2 = tuesday 3 = wednesday 4 = thursday 5 = friday
53-54	No. of persons in household	Numeric or blank
55-82	No. of trip and reason	Alphanumeric or blank
83	No. of Cars	Numeric or blank
84	No. of Trips by this household	Numeric or blank
85-98	Civic No. of Destination	Alphanumeric or blank
99-102	'Equivalent' Civic No. of destination	Numeric or blank

Position	Subject	Description
103-122	Street or Building name of destination	Alphanumeric or blank
123-125	Destination Zone No.	Numeric; blank if 'no trip' taken
126-155	Occupation	Alphanumeric or blank
156-157	Occupation Code	Numeric or blank
158-177	Company Name	Numeric or blank
178-179	Company Code	Numeric or blank
180	Sex	Numeric or blank; 1 = male, 2 = female
181-182	Mode of transport	Numeric or blank; 1 = auto driver, 2 = auto passenger, 3 = transit passenger, 4 = walk or cycle; 181 contains departure mode and 182 arrival mode
183-190	Departure hour at origin	Alphanumeric or blank
191-198	Return hour at origin	Alphanumeric or blank
198-201	Why do you travel by transit?	Alphanumeric or blank; 1 = no driver's permit, 2 = no car available, 3 = parking too far from work place, 4 = parking too expensive near work, 5 = cheaper by bus, 6 = other
202	Do you need the car for work?	Numeric or blank; 1 = yes, 2 = no
203	Total income of household	Numeric or blank; 1 = 0-$5,000; 2 = $5,001-$10,000; 3 = $10,001-$15,000; 4 = $15,001-20,000; 5 = $20,001 and higher; 6 = no answer
204	Are you captive to transit?	Question asked only in student mail survey; numeric or blank; 1 = non captive 2 = captive

APPENDIX 3

O/D EXPANSION FACTORS

THE CITY OF WINNIPEG

WORK TRIP TO TOTAL TRIP EXPANSION FACTORS 1976 AM PEAK VEHICLE TRIPS

Factor 5

O \ D	0	1	2	3	4	5	6	7	8
0	2.106	2.428	1.981	1.846	2.111	2.000	1.931	2.025	[illegible]
1	1.167	1.584	1.199	1.199	1.135	1.170	1.167	1.149	[illegible]
2	1.150	1.595	1.210	1.210	1.135	1.235	1.198	1.198	[illegible]
3	1.159	1.474	1.166	1.166	1.135	1.170	1.159	1.150	[illegible]
4	1.365	1.338	1.070	1.067	1.122	1.210	1.365	1.319	[illegible]
5	1.226	1.153	1.029	1.029	1.122	1.155	1.226	[illegible]	[illegible]
6	1.364	1.333	1.333	1.333	1.434	1.425	1.364	[illegible]	[illegible]
7	1.823	2.164	1.649	1.654	1.434	1.840	[illegible]	[illegible]	[illegible]
8	1.552	1.990	1.449	1.448	1.435	1.543	1.465	1.552	[illegible]
9	1.319	–	–	–	1.234	–	–	1.271	–

AUG 30,

1/9/77

THE CITY OF WINNIPEG

WORK TRIP TO TOTAL TRIP EXPANSION FACTORS
1976 A.M. PEAK VEHICLE TRIPS

FACTOR 6

O \ D	0	1	2	3	4	5	6	7	8	9
0	~~1.05~~ 3.49	~~2.26~~ 4.00	~~1.92~~ 3.29	~~1.77~~ 3.15	~~2.06~~ 3.49	~~1.92~~ 3.31	~~1.71~~ 3.22	~~1.79~~ 3.35	~~1.79~~ 3.34	[illegible] 3.3
1	1.15	1.27	1.09	1.09	1.13	1.17	1.15	1.12	1.15	1.1[illegible]
2	1.12	1.29	1.09	1.09	1.13	1.23	1.16	1.16	1.16	1.1[illegible]
3	1.13	1.26	1.07	1.08	1.12	1.17	1.13	1.12	1.13	1.1[illegible]
4	1.35	1.29	1.03	1.02	1.12	1.21	1.34	1.30	1.35	1.2[illegible]
5	1.21	1.10	1.02	1.02	1.12	1.15	1.21	1.24	1.21	1.1[illegible]
6	1.30	1.30	1.29	1.29	1.40	1.39	1.20	1.20	1.20	1.2[illegible]
7	1.61	2.09	1.60	1.60	1.40	1.80	1.49	1.55	1.49	1.5[illegible]
8	1.37	1.93	1.40	1.40	1.40	1.50	1.31	1.37	1.31	1.3[illegible]
9	1.24	–	–	–	1.21	–	–	1.26	–	–

~~OCT 25/77~~

Version used 23 Nov 77.
LOT.

THE CITY OF WINNIPEG

WORK TRIP TO TOTAL TRIP EXPANSION FACTORS 1976 AM PEAK VEHICLE TRIPS

FACTOR 7

D	0	1	2	3	4	5	6	7	8	9
0	3.50	4.00	3.31	3.23	3.50	3.31	1.14	3.40	3.30	3.30
1	1.09	1.44	1.09	1.16	1.02	1.05	1.09	1.05	1.19	1.10
2	1.12	1.60	1.21	1.09	1.13	1.24	1.16	1.16	1.20	1.20
3	1.06	1.50	1.06	1.06	1.02	1.05	1.06	1.05	1.16	1.05
4	1.30	1.30	1.10	1.10	1.02	1.10	1.15	1.10	1.35	1.15
5	1.02	1.20	1.02	1.02	1.02	1.05	1.02	1.05	1.23	1.02
6	1.01	1.15	1.01	1.01	1.02	1.01	1.01	1.01	1.01	1.01
7	1.82	2.20	1.65	1.64	1.43	1.84	1.68	1.75	1.69	1.69
8	1.15	2.06	1.10	1.10	1.02	1.10	1.10	1.15	1.10	1.10
9	1.19	—	—	—	1.02	—	—	1.05	—	—

DEC/77

THE CITY OF WINNIPEG

WORK TRIP TO TOTAL TRIP EXPANSION FACTORS 1976 AM PEAK VEHICLE TRIPS

FACTOR 8

	0	1	2	3	4	5	6	7	8	9	59
P	6.56	1.11	6.35	6.23	6.72	6.39	6.86	6.54	7.29	6.82	3.50
1	1.09	1.44	1.09	1.10	1.02	1.05	1.09	1.05	1.19	1.10	1.02
2	1.12	1.60	1.21	1.09	1.13	1.24	1.16	1.16	1.20	1.20	1.13
3	1.06	1.50	1.06	1.06	1.02	1.05	1.06	1.05	1.16	1.05	1.02
4	1.30	1.30	1.10	1.10	1.02	1.10	1.15	1.10	1.35	1.15	1.02
5	1.02	1.20	1.02	1.02	1.02	1.05	1.02	1.05	1.23	1.02	1.02
6	1.01	1.15	1.01	1.01	1.02	1.01	1.01	1.01	1.01	1.01	1.02
7	1.82	2.20	1.65	1.64	1.43	1.84	1.68	1.75	1.69	1.65	1.43
8	1.15	2.00	1.10	1.10	1.02	1.10	1.10	1.15	1.10	1.10	1.02
9	1.19	—	—	—	1.02	—	—	1.05	—	—	1.02
A	1.30	1.30	1.10	1.10	1.02	1.10	1.15	1.10	1.35	1.15	1.02

Figure 9.4

APPENDIX 4

EMME TRANSIT CODING FORMS

EMME

PROJECT .....

CODED BY .....

TRANSIT LINE CODING FORM

DATE ..... PAGE ..... OF .....

UPDATE CODE (A,M,D) [ ] 1

LINE NO. [ ] 2–5

NAME [ ] 6–25

HEADWAY [ ] 28–31

LENGTH [ ] 32–34 . [ ] 35–36

SPEED [ ] 37–40 . [ ] 41

TYPE [ ] 42–46

LAYOVER [ ] 48–50

VEHICLES [ ] 53–55

USER INFORMATION [ ] 73–80

NODE SEQUENCE

	LINE	NODE	dir	NODE	dir	NODE	dir	NODE	dir	NODE	dir	NODE	dir	NODE	dir	NODE	dir	NODE	dir	NODE	dir	NODE	dir	NODE	dir		USER INFORMATION
	1 2 3 4 5	6 7 8 9	10	11 12 13 14	15	16 17 18 19	20	21 22 23 24	25	26 27 28 29	30	31 32 33 34	35	36 37 38 39	40	41 42 43 44	45	46 47 48 49	50	51 52 53 54	55	56 57 58 59	60	61 62 63 64	65	66 67 68 69	70	71 72	73 74 75 76 77 78 79 80
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3																													
4																													
5																													
6																													

OMME-50-0

27/7/76

EMME

CODED BY .....

PROJECT .....

TRANSIT NODE - ROAD NODES
CORRESPONDANCE

DATE ..... PAGE .....OF .....

No.	TRANSIT NODE	CORRESPONDING ROAD NODES	USER INFORMATION
1	2 3 4 5	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80
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emme-51-0

27-7-76

EMME

PROJECT .....

CODED BY .....

TRANSIT LINK CODING FORM

DATE ..... PAGE .....OF .....

	ORIGIN NODE	DESTN NODE	S	TIME	REVERSE TIME		USER INFORMATION
	1 2 3 4 5	6 7 8 9 10	11	12 13 14 15 16 17	18 19 20 21 22 23	24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74 75 76 77 78 79 80
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emme-52-0

27-7-76

EMME

PROJECT .....

CODED BY .....

TRANSIT ACCESS LINK CODING FORM

DATE ..... PAGE .....OF .....

	ZONE CENTROID	ACCESS NODE	S	TIME TO NODE	TIME TO CENTROID		USER INFORMATION
	1 2 3 4 5	6 7 8 9 10	11	12 13 14 15 16 17	18 19 20 21 22 23	24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80
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emme-33-0

27-7-76